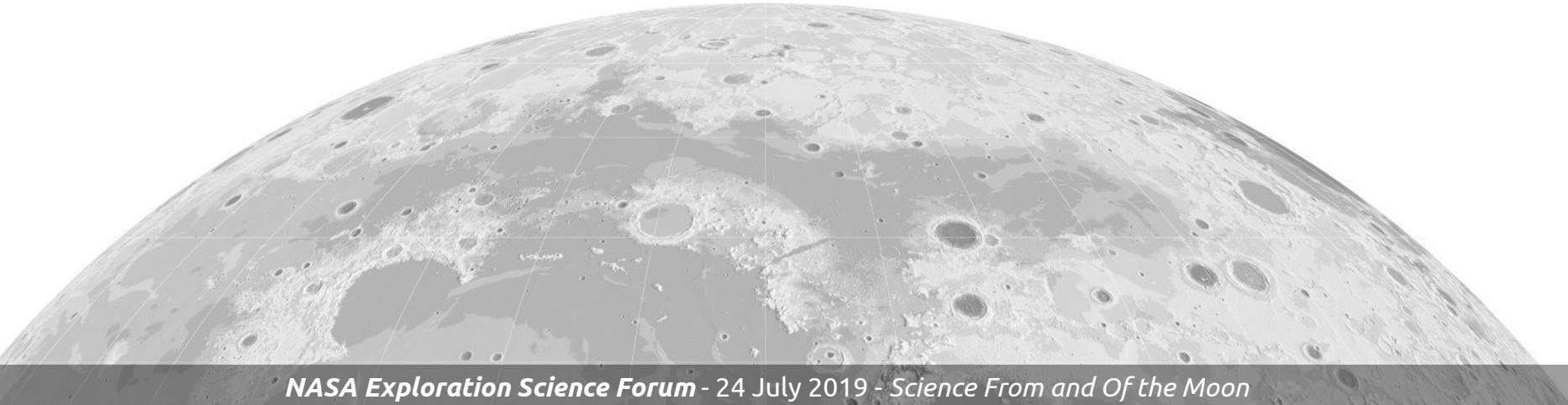


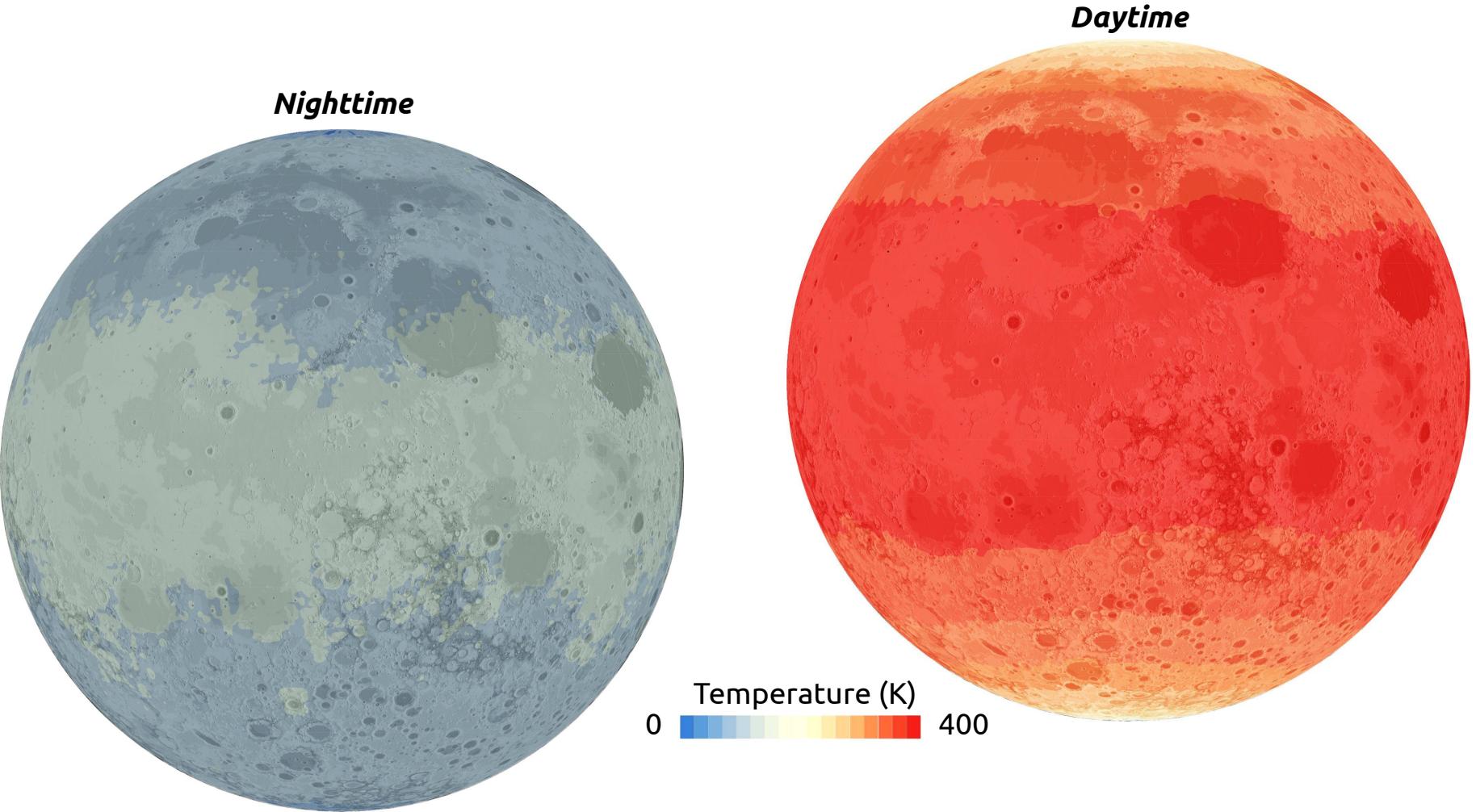
Investigating diurnal changes in the normal albedo of the lunar surface at 1064 nm: A new analysis with the Lunar Orbiter Laser Altimeter

Ariel N. Deutsch¹, Gregory A. Neumann², James W. Head¹, Paul G. Lucey³

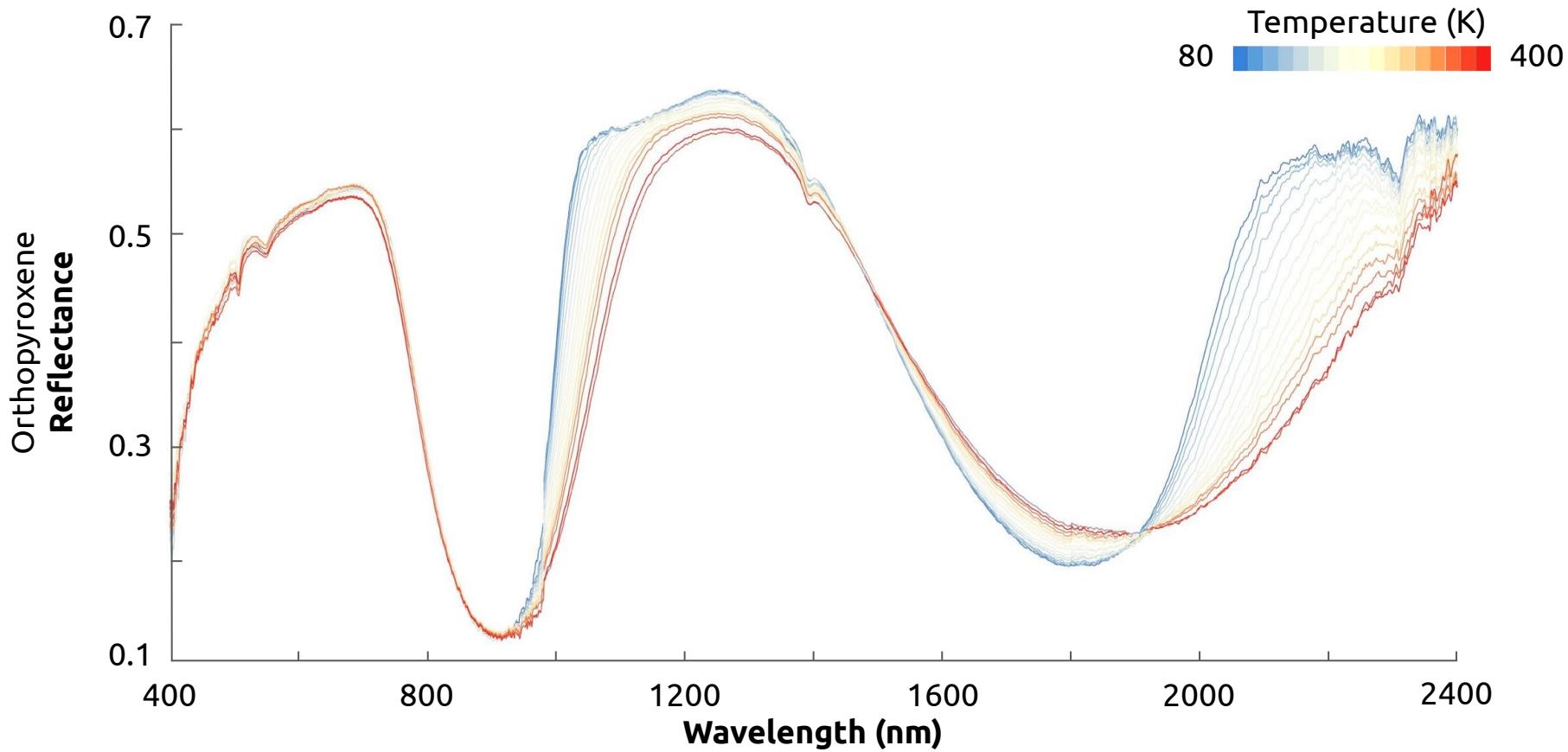
¹Department of Earth, Environmental and Planetary Sciences, Brown University
²Planetary Geology, Geophysics, and Geochemistry Laboratory, NASA Goddard Space Flight Center
³Hawaii Institute of Geophysics and Planetology, University of Hawaii at Manoa



INTRODUCTION *thermal environment at the Moon*

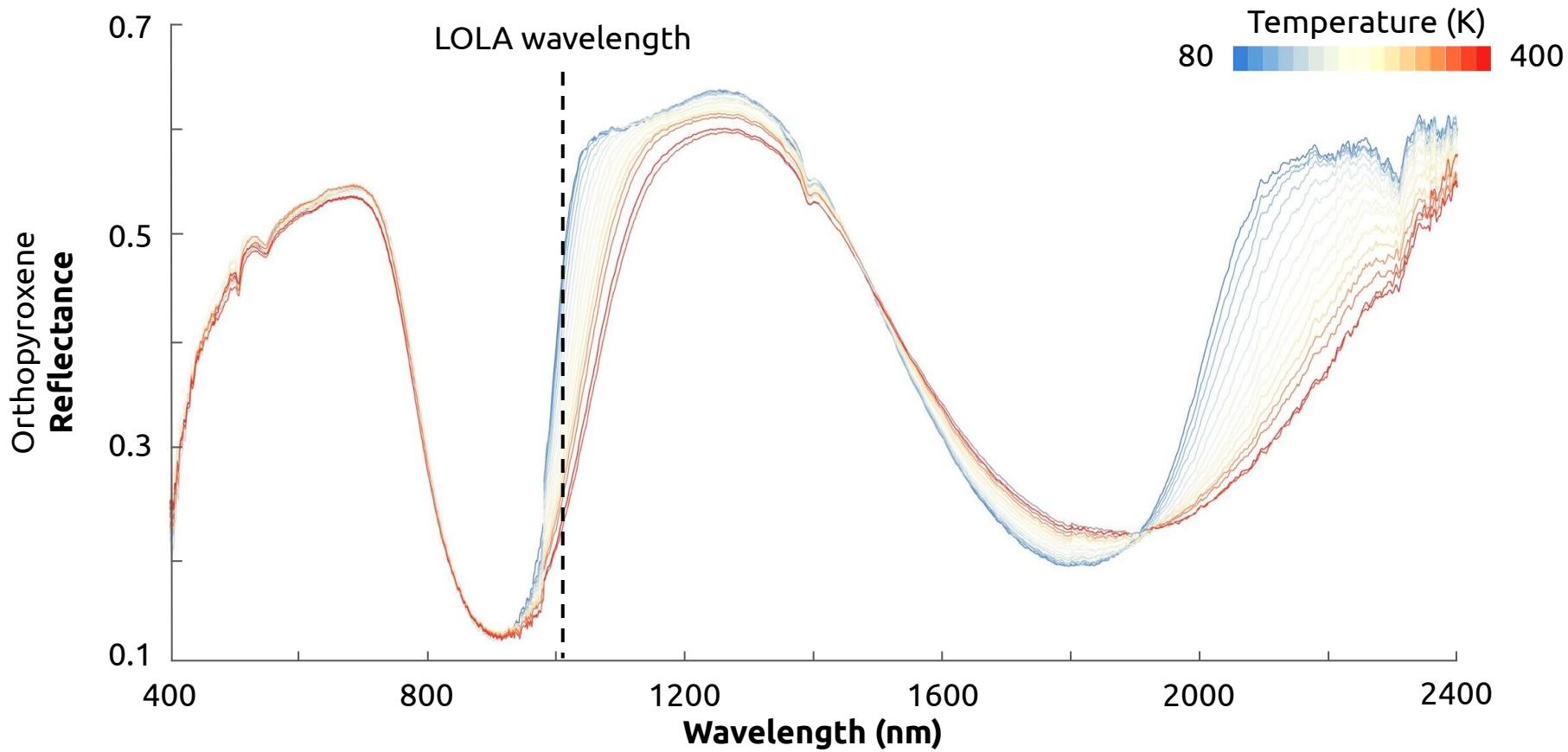


INTRODUCTION *temperature-dependent spectral changes*



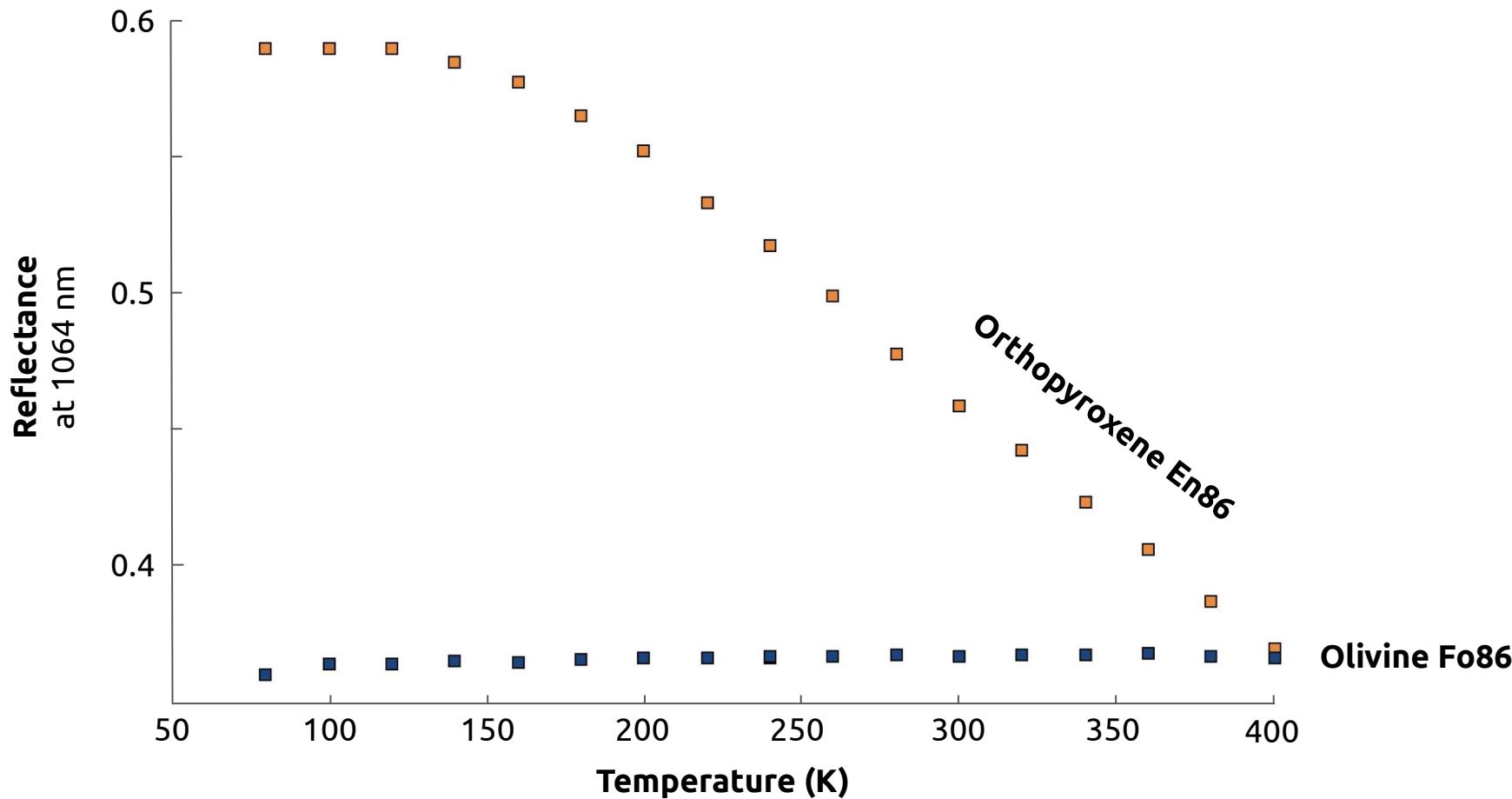
Data from Hinrichs et al. (1999)

INTRODUCTION *temperature-dependent spectral changes*

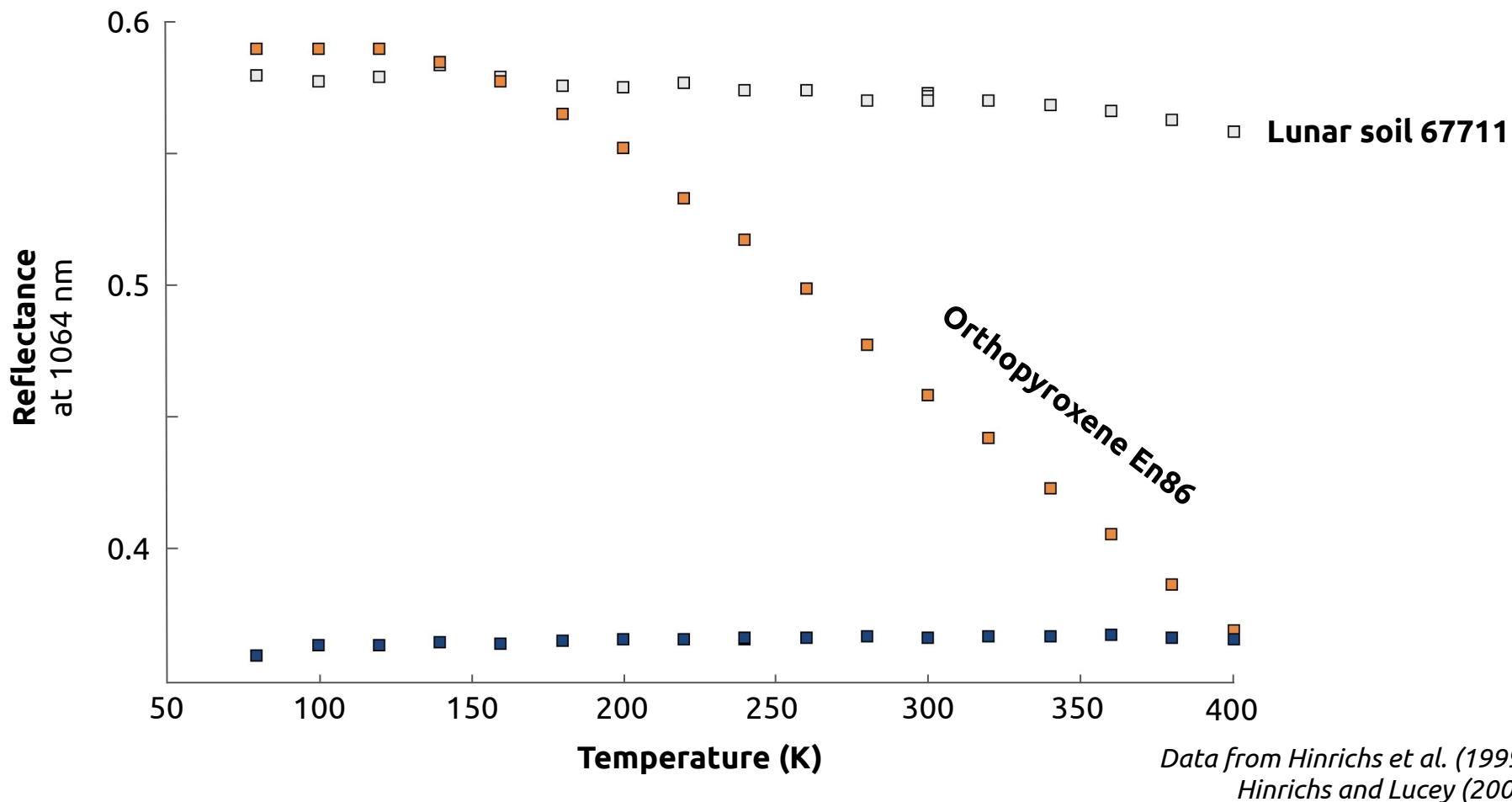


Data from Hinrichs et al. (1999)

INTRODUCTION *temperature-dependent spectral changes*



INTRODUCTION *temperature-dependent spectral changes*





RESEARCH QUESTION

**How does the surface reflectance of the Moon,
as measured from orbit by LOLA at 1064 nm,
change over the course of a lunar day?**

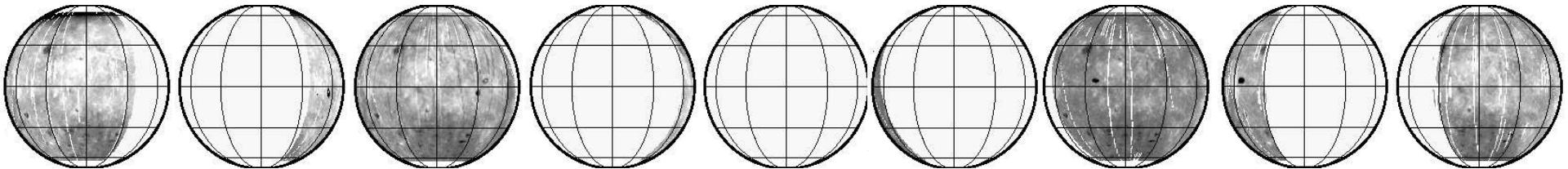
METHODS *diurnal reflectance changes*

Determine the reflectance and temperature of the surface
for local hours 07:00–16:00 in $1^\circ \times 1^\circ$ spatial bins from 65°S to 65°N .

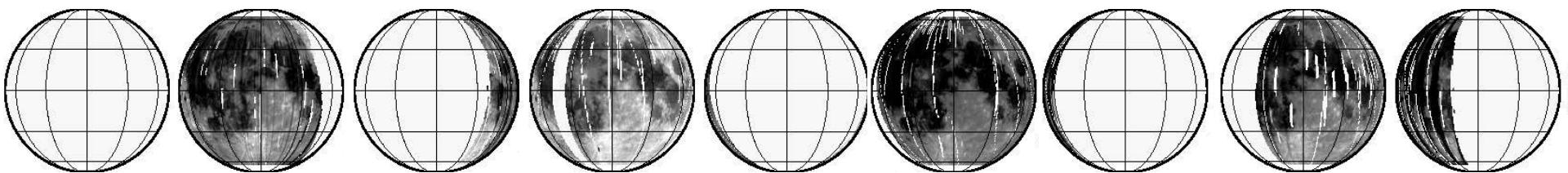
RESULTS *diurnal reflectance changes*

Determine the **reflectance** and temperature of the surface
for local hours 07:00–16:00 in $1^\circ \times 1^\circ$ spatial bins from 65°S to 65°N .

$0^\circ\text{N}, 180^\circ\text{E}$



$0^\circ\text{N}, 0^\circ\text{E}$



07:00

08:00

09:00

10:00

11:00

12:00

13:00

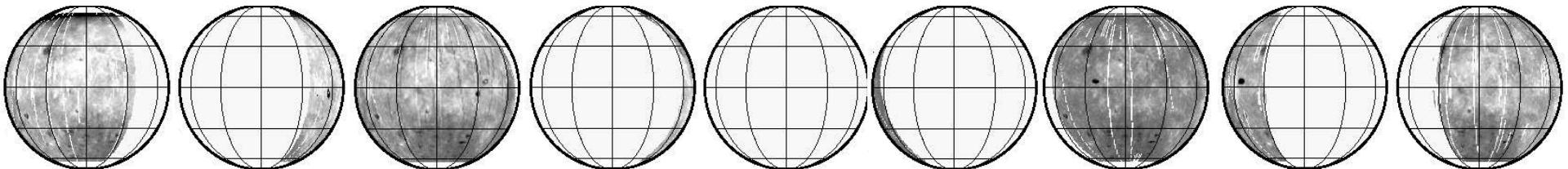
14:00

15:00

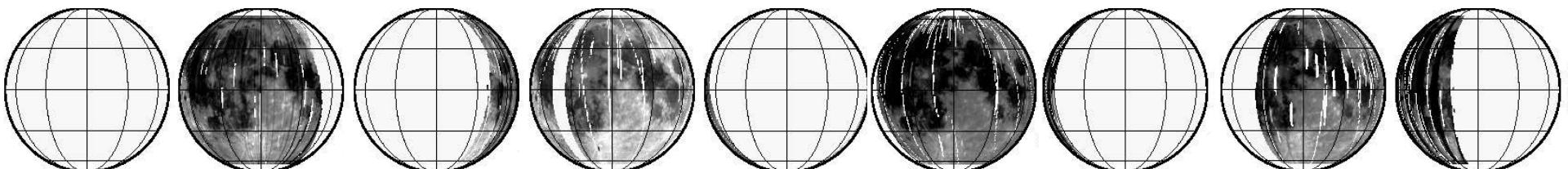
RESULTS *diurnal reflectance changes*

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$0^\circ\text{N}, 0^\circ\text{E}$



07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

294 K

392 K

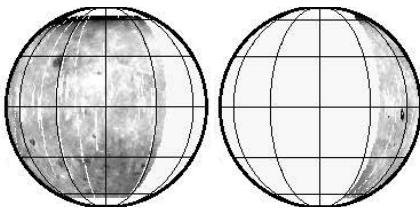
342 K



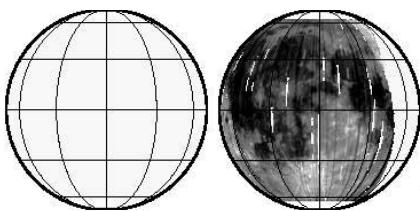
RESULTS *diurnal reflectance changes*

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for local hours 07:00–16:00 in $1^\circ \times 1^\circ$ spatial bins from 65°S to 65°N .

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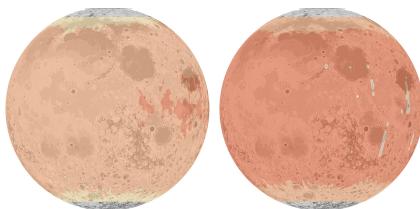
$0^\circ\text{N}, 0^\circ\text{E}$



07:00

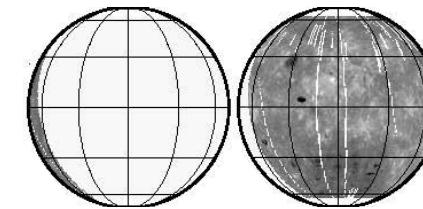
08:00

Brighter

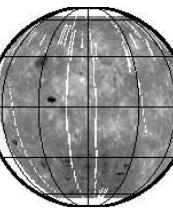


294 K

Colder



12:00



13:00

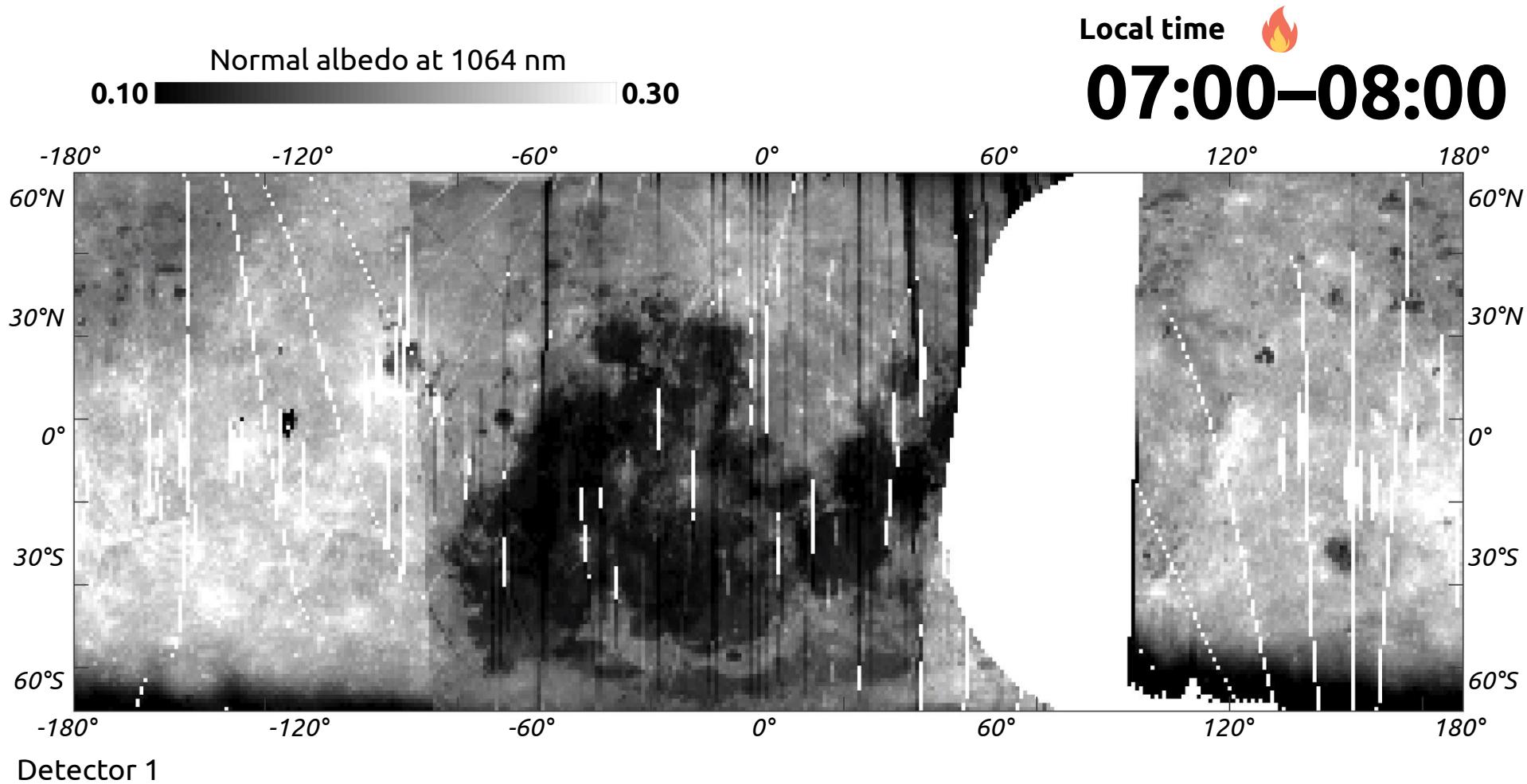
Darker



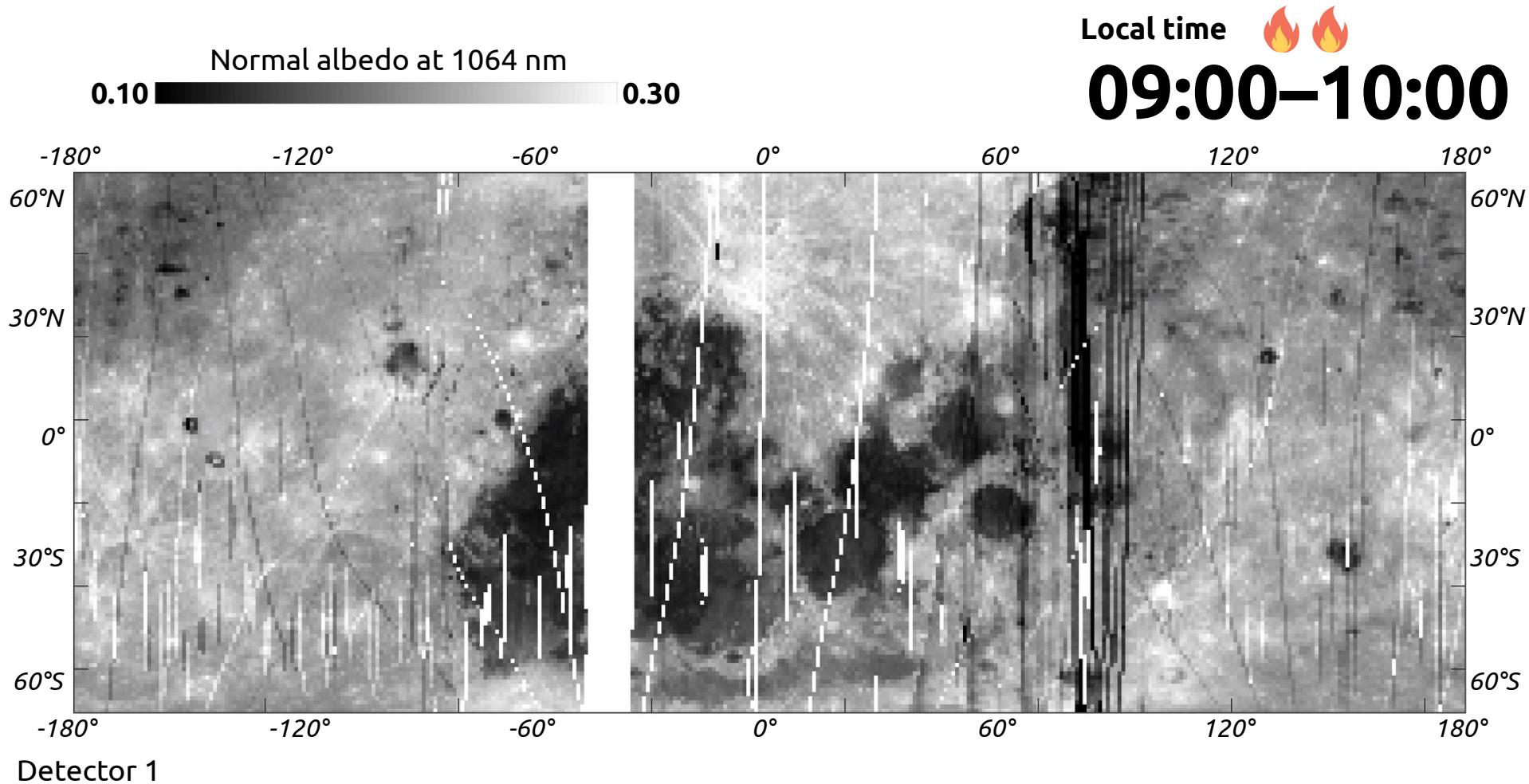
392 K

Warmer

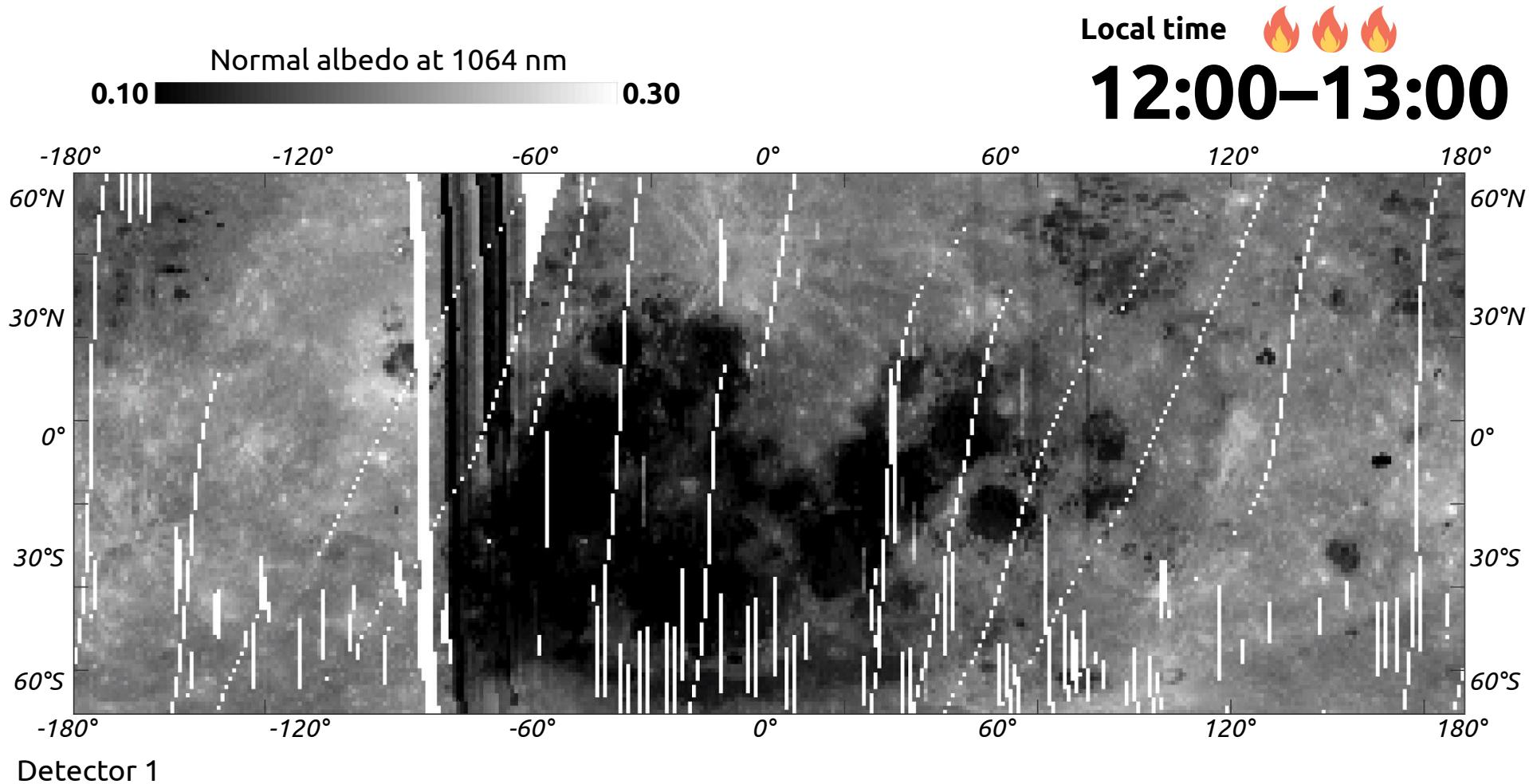
RESULTS *diurnal reflectance changes*



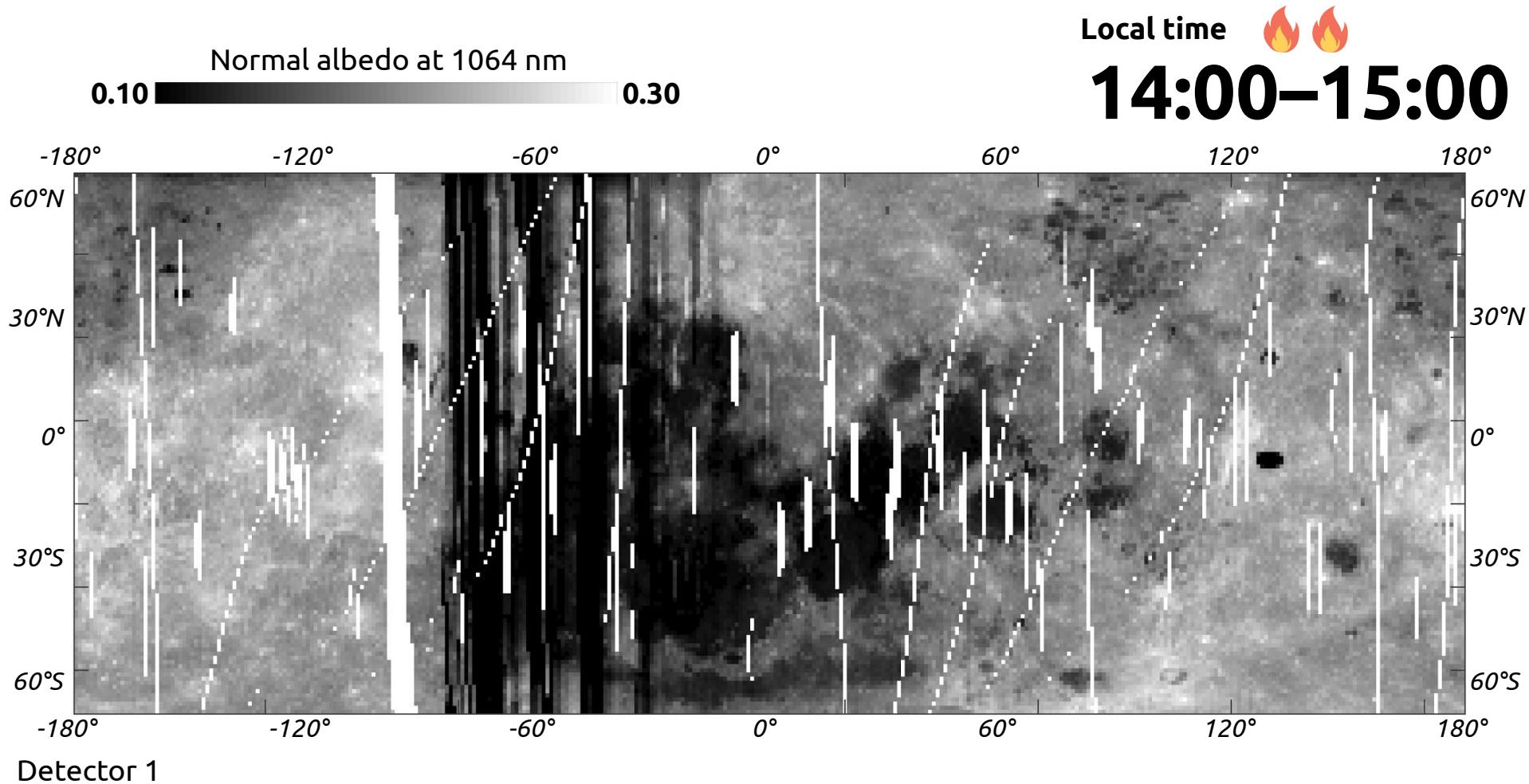
RESULTS *diurnal reflectance changes*



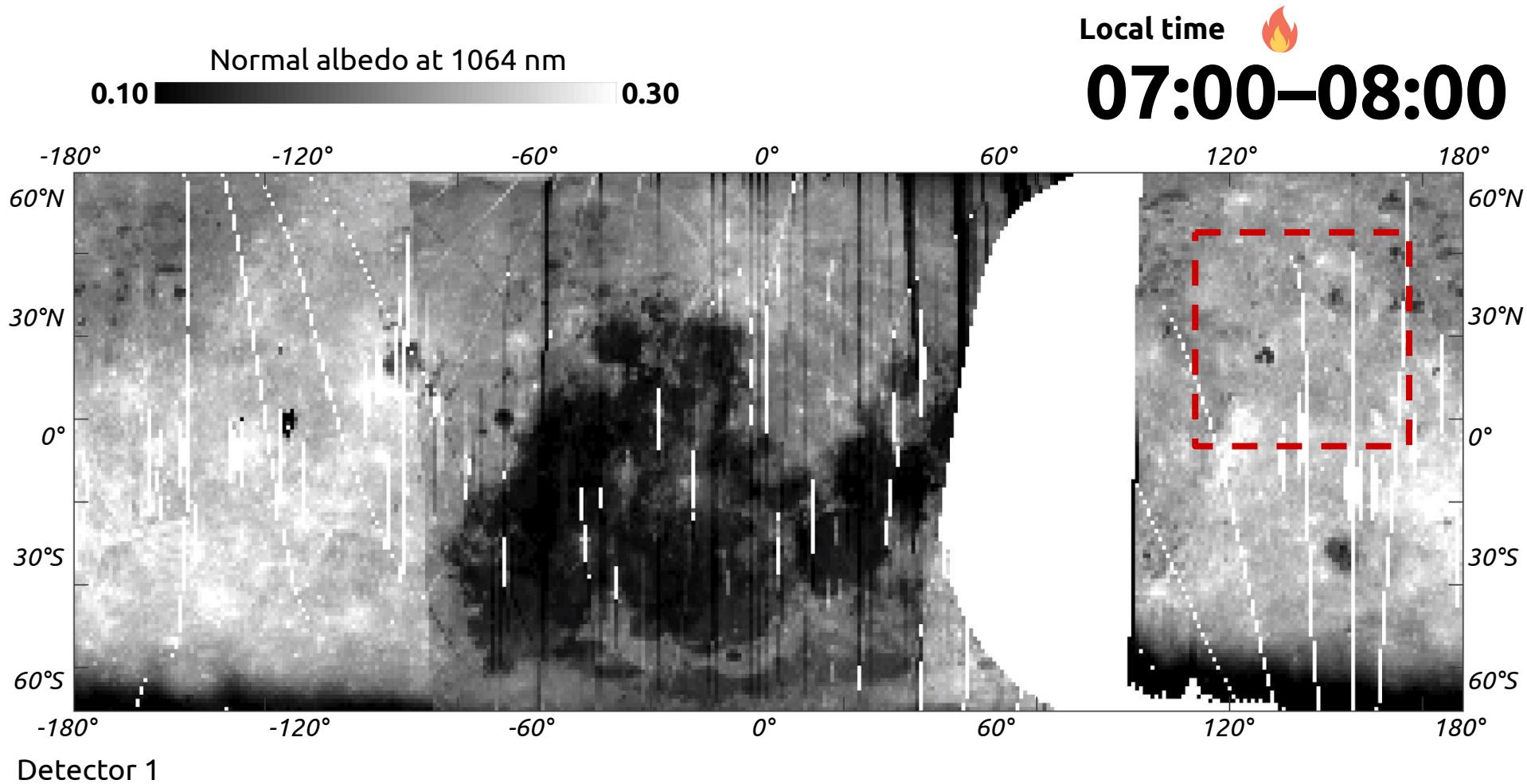
RESULTS *diurnal reflectance changes*



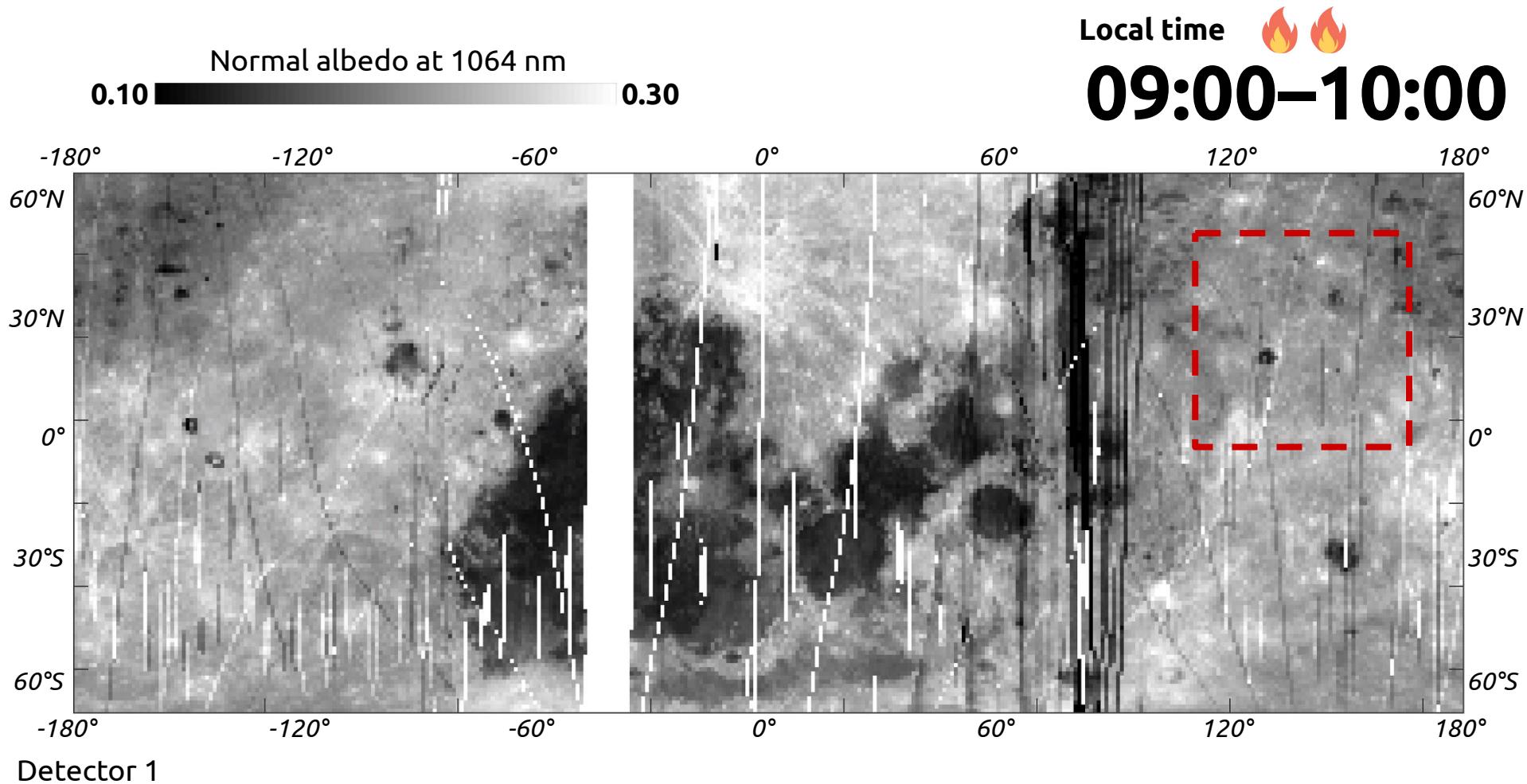
RESULTS *diurnal reflectance changes*



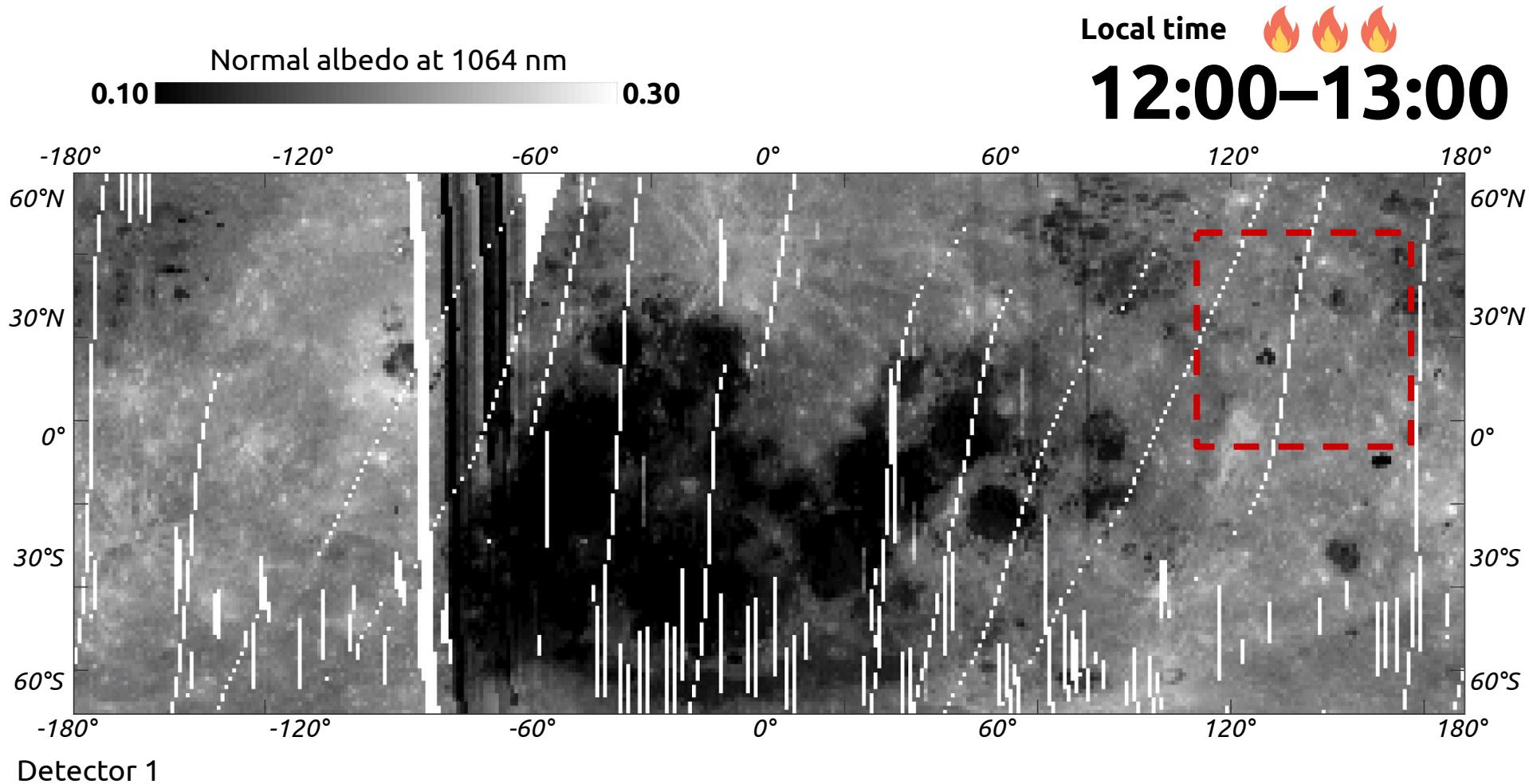
RESULTS *diurnal reflectance changes*



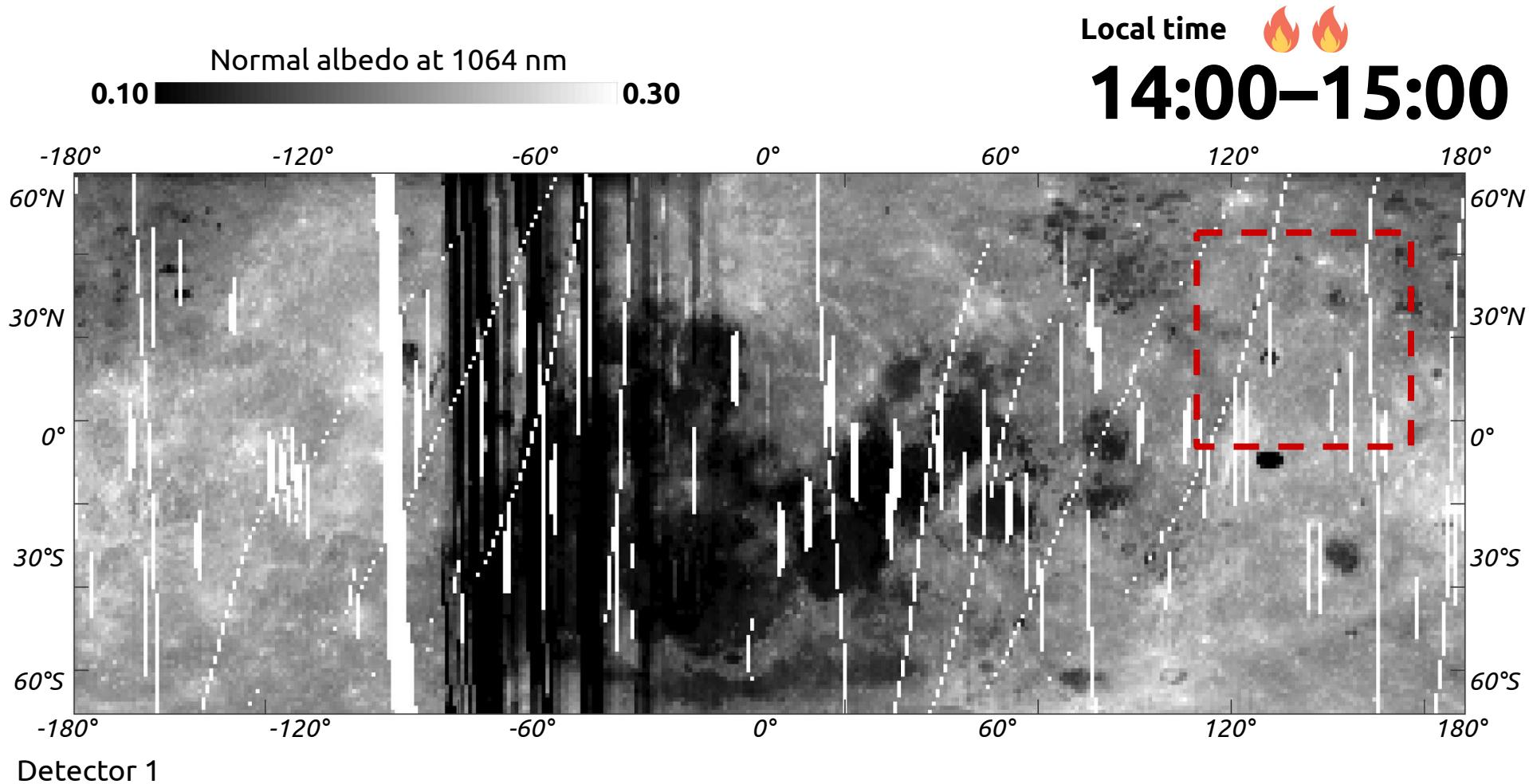
RESULTS *diurnal reflectance changes*



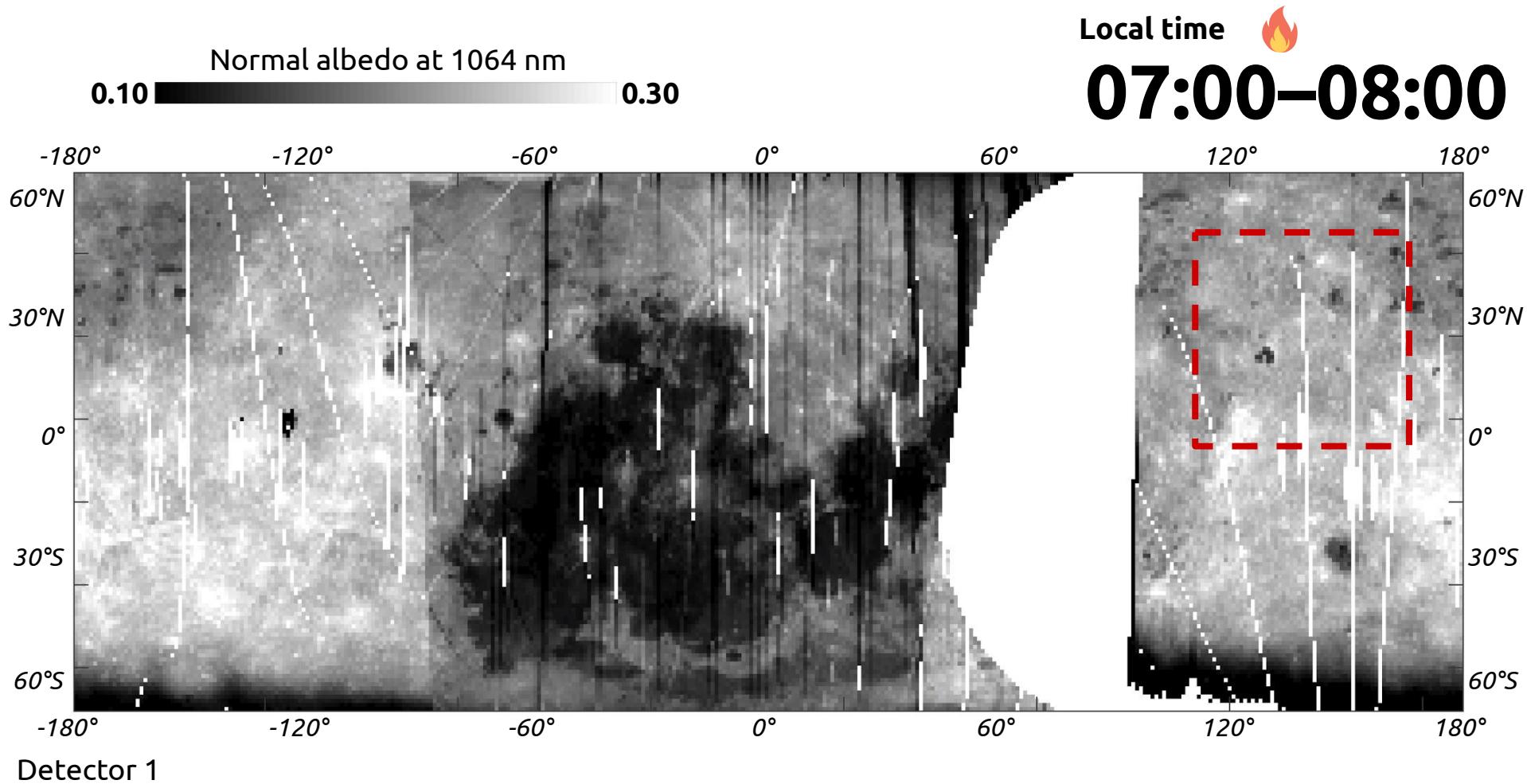
RESULTS *diurnal reflectance changes*



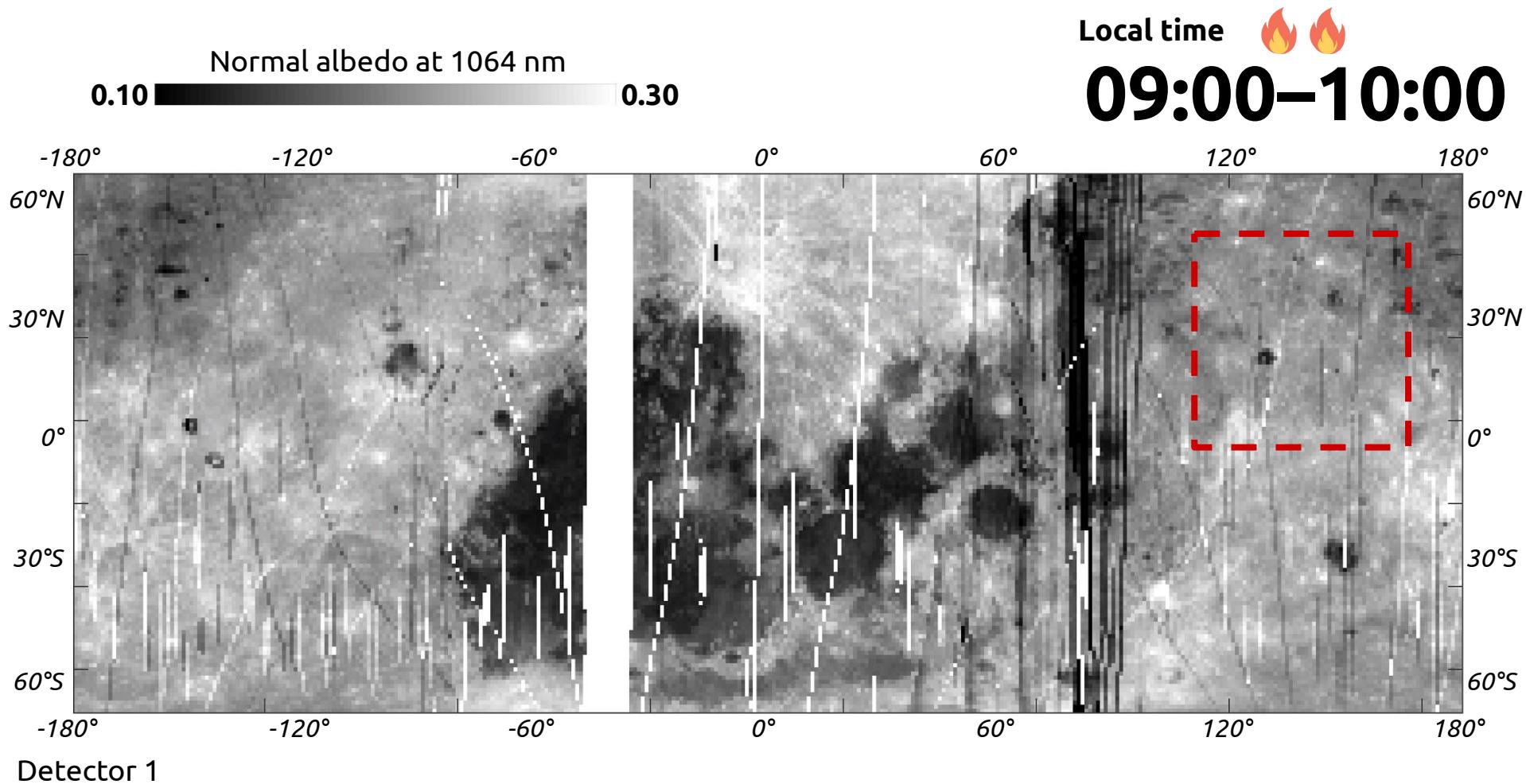
RESULTS *diurnal reflectance changes*



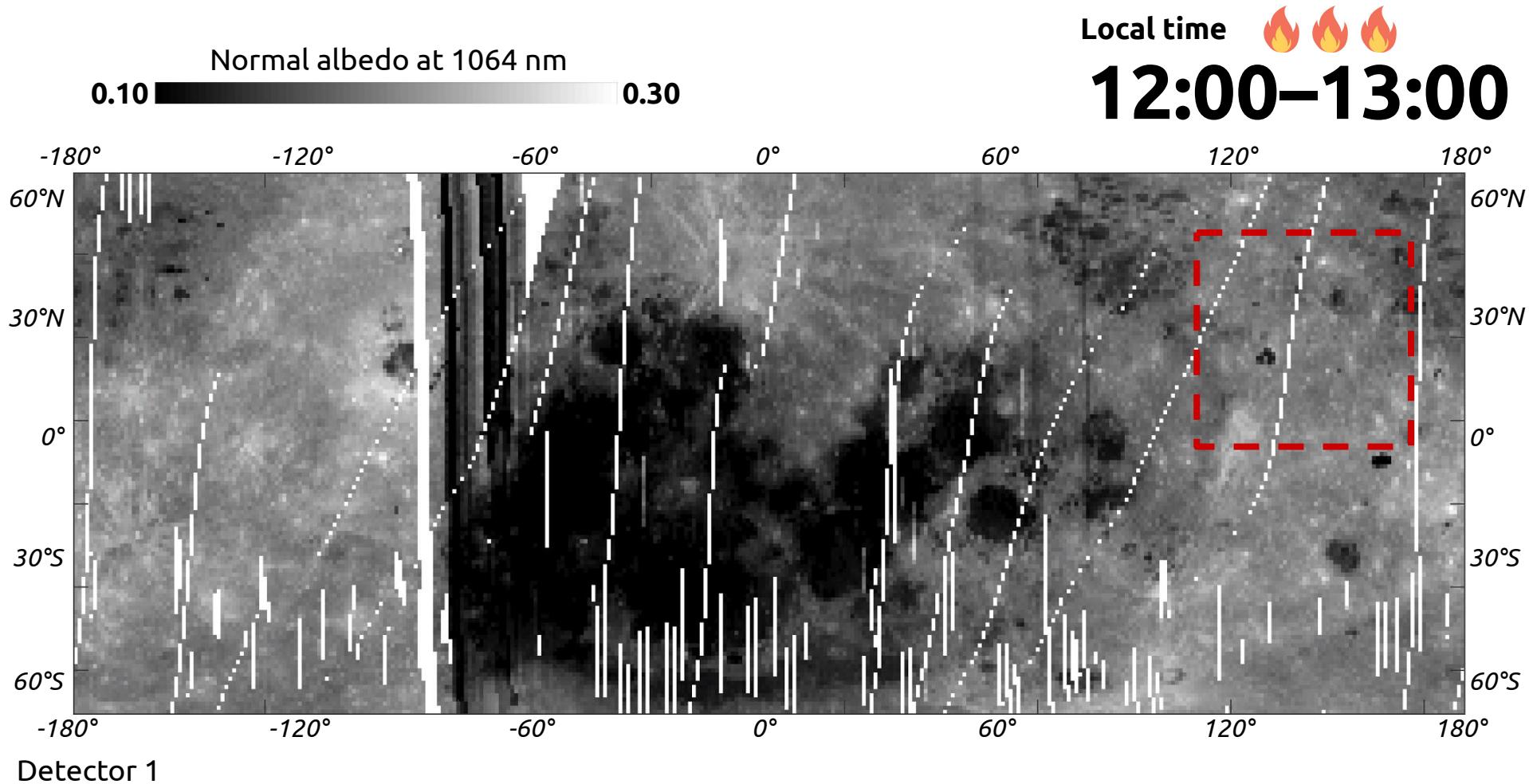
RESULTS *diurnal reflectance changes*



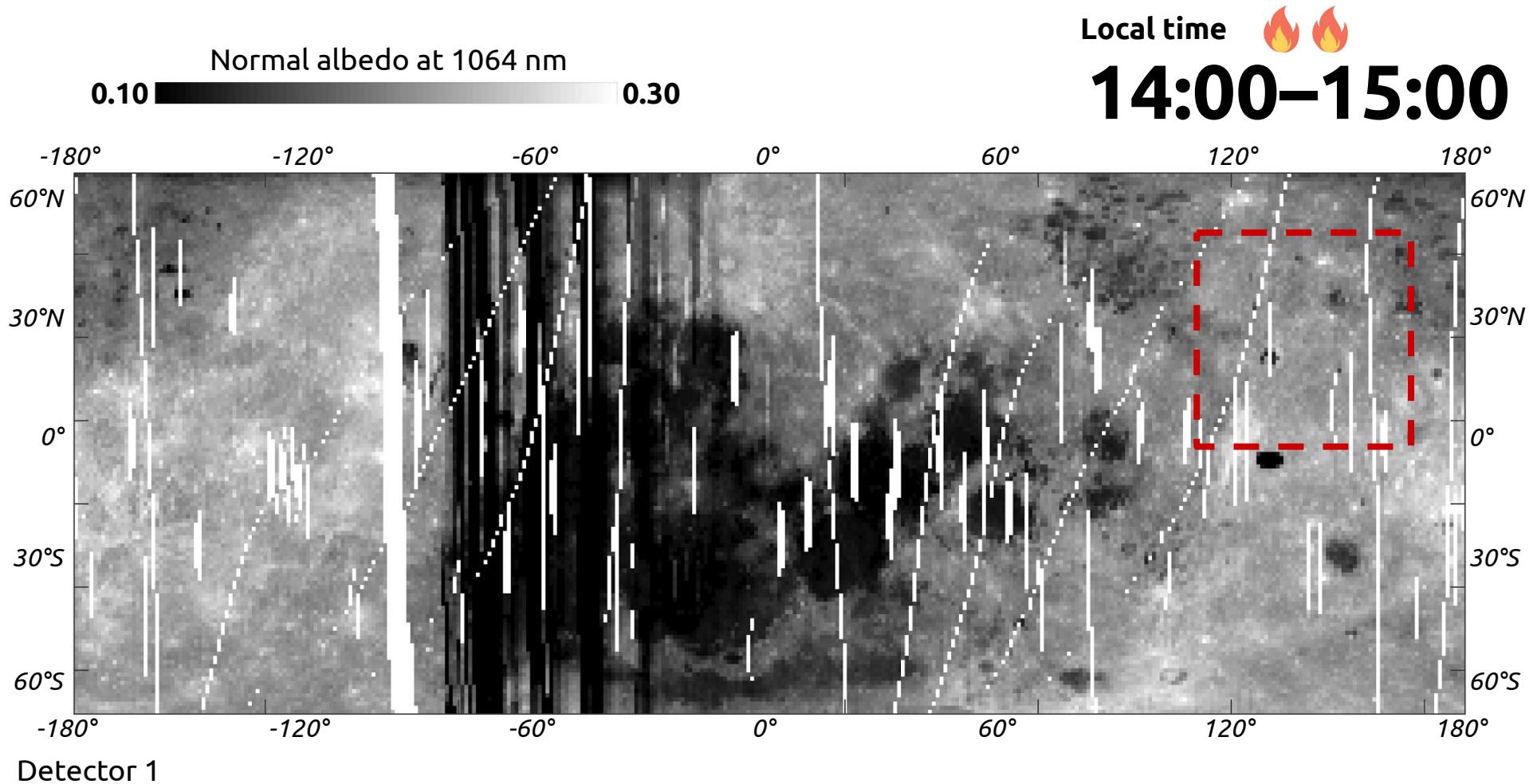
RESULTS *diurnal reflectance changes*



RESULTS *diurnal reflectance changes*

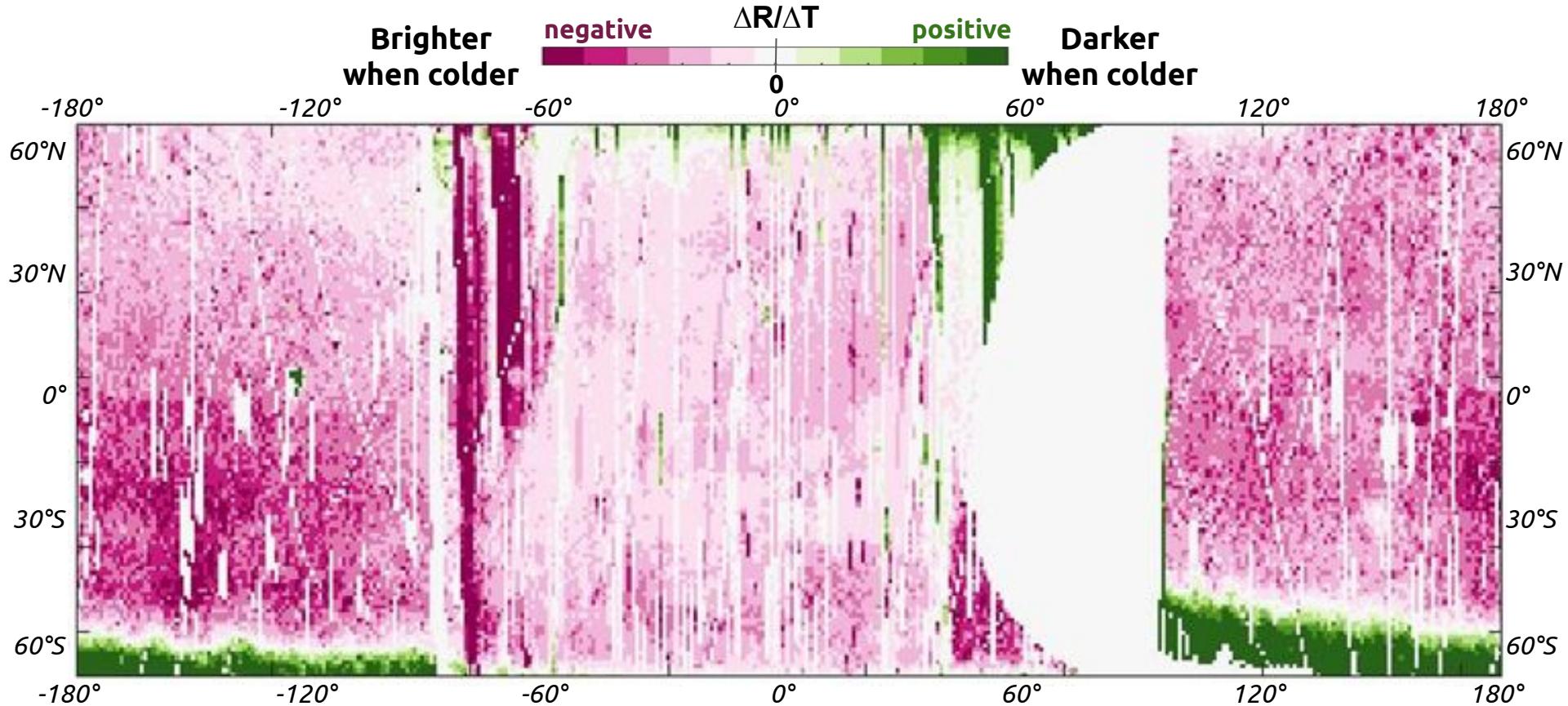


RESULTS *diurnal reflectance changes*



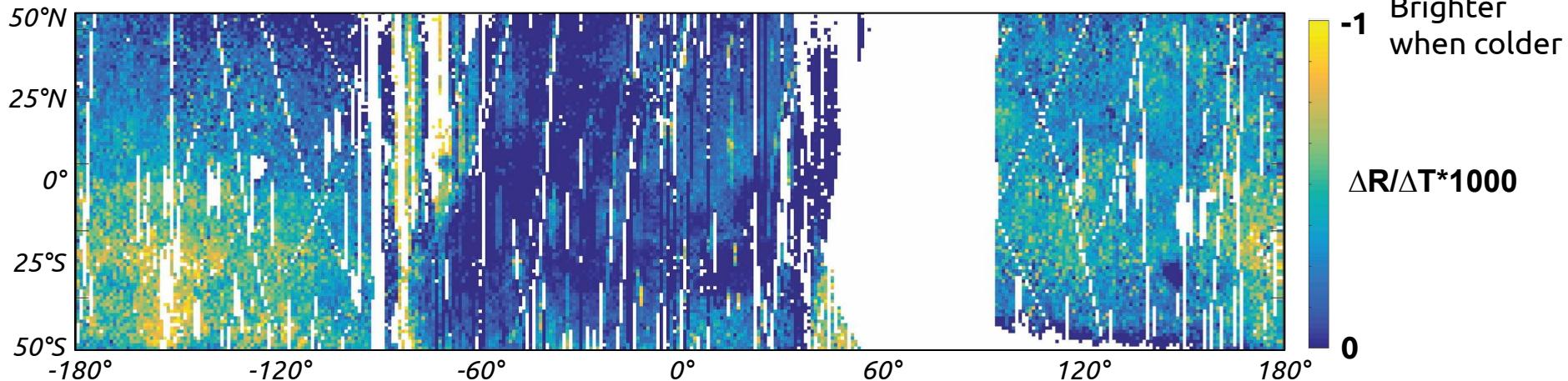
RESULTS *diurnal reflectance changes*

What temperature-dependent changes are occurring?



RESULTS *diurnal reflectance changes*

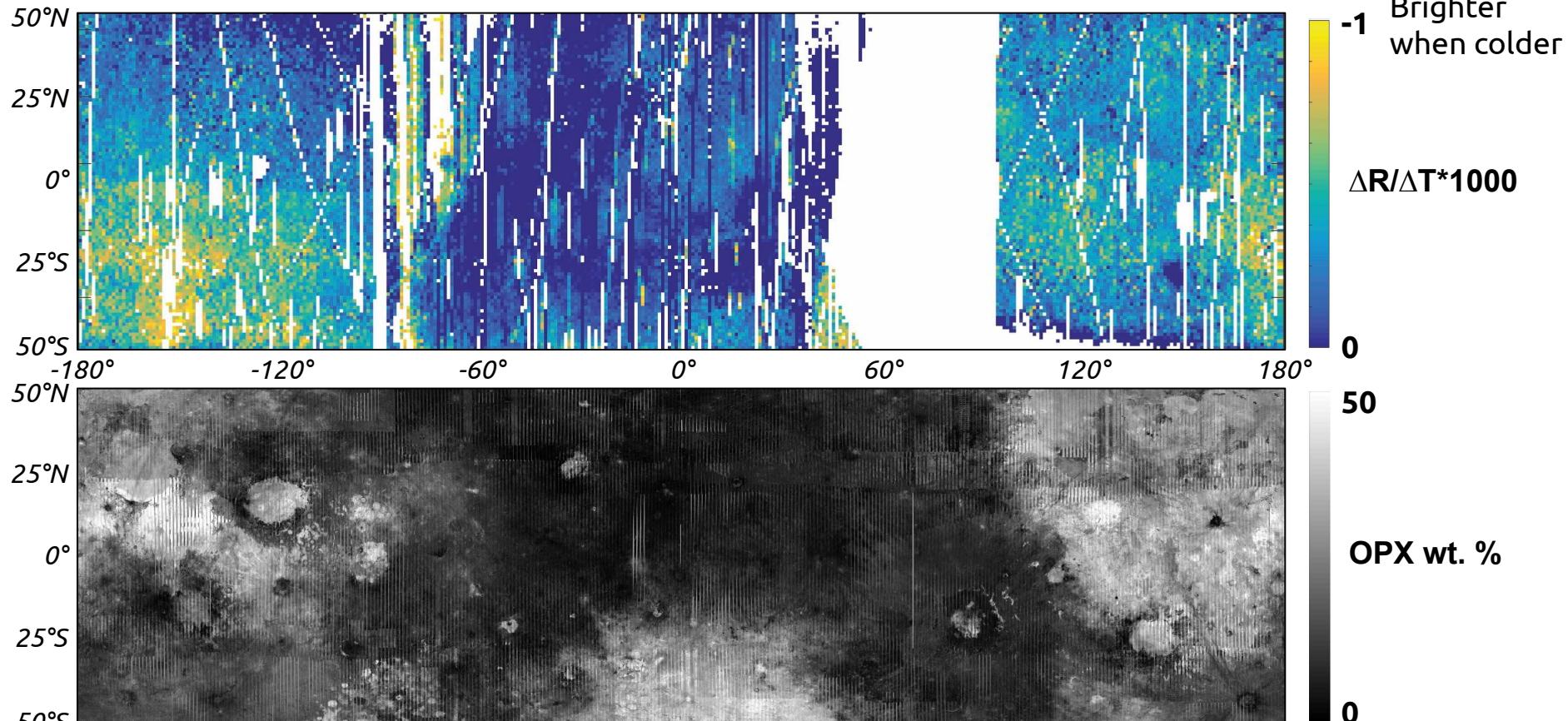
What temperature-dependent changes are occurring?



1. LOLA measures a higher surface reflectance across the lunar surface at colder temperatures.
2. The change in albedo is relatively small (only a few %) from 07:00 to 12:00.
3. The $\Delta R/\Delta T \times 1000$ is [-1 0] 1/K on average.

IMPLICATIONS LOLA as a mineralogical sensor?

Where are the greatest temperature-dependent changes occurring?



Lemelin et al. (2016)

CONCLUSIONS

We observe a higher normal albedo of the lunar surface when the temperature is lower, as measured by LOLA at 1064 nm.



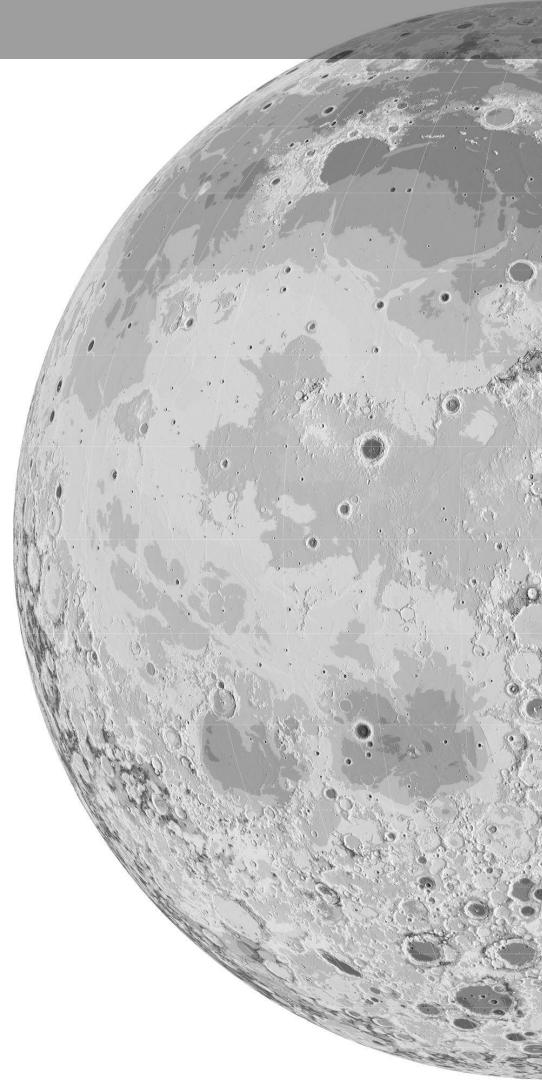
This is consistent with:

1. Laboratory observations of pure minerals.
(Singer and Roush, 1985; Roush and Singer, 1986, 1987; Hinrichs and Lucey, 2002)
2. Ground-based observations of A-type asteroids.
(Lucey et al., 1998)
3. Spacecraft-based observations of Eros.
(Lucey et al., 2002)

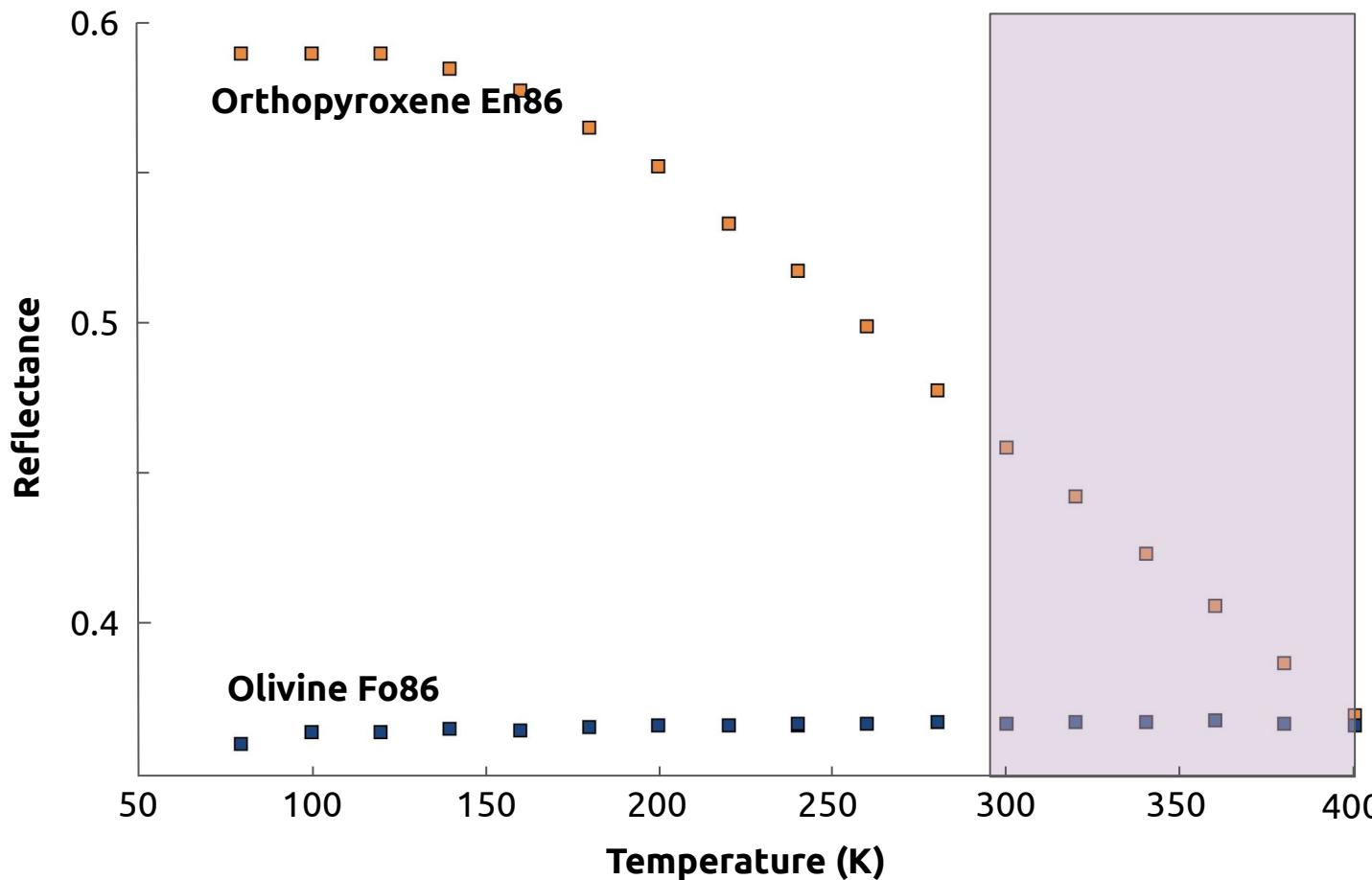
On the space-weathered Moon, the magnitude of temperature-dependent spectral effects is relatively low.

Ongoing work consists of determining the causes of these changes.

 Future science of and from the Moon should account for temperature-dependent spectral effects.

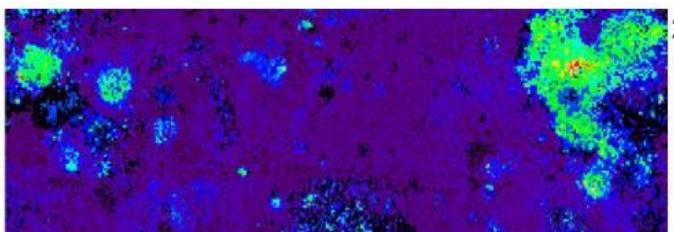


IMPLICATIONS LOLA as a mineralogical sensor

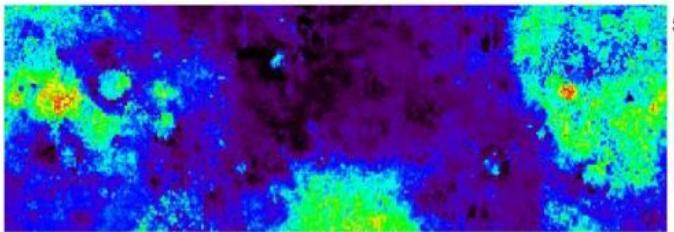


Data from Hinrichs et al. (1999)

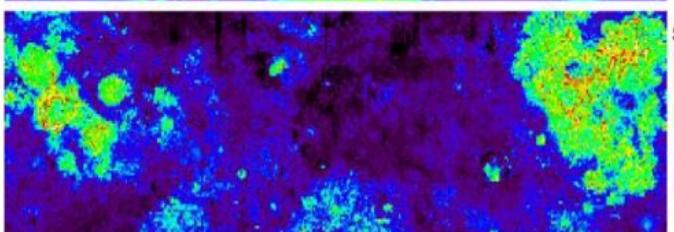
IMPLICATIONS LOLA as a mineralogical sensor



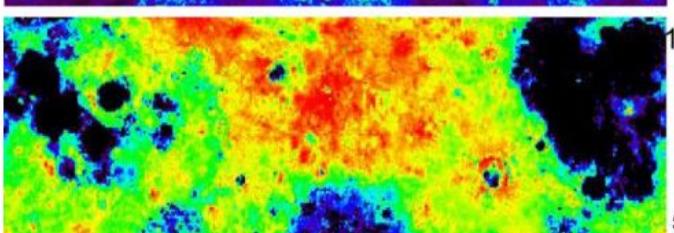
Olivine
25



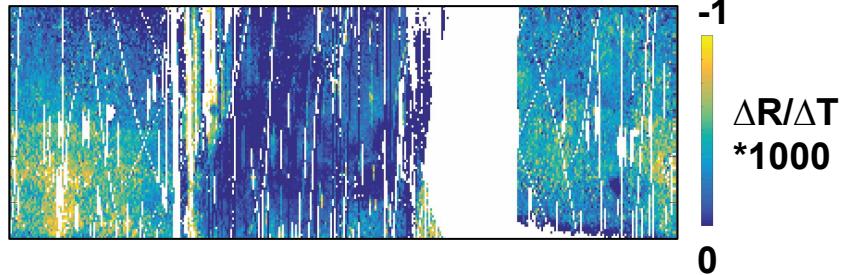
Low-Ca
Pyroxene
50



Clinopyroxene
50

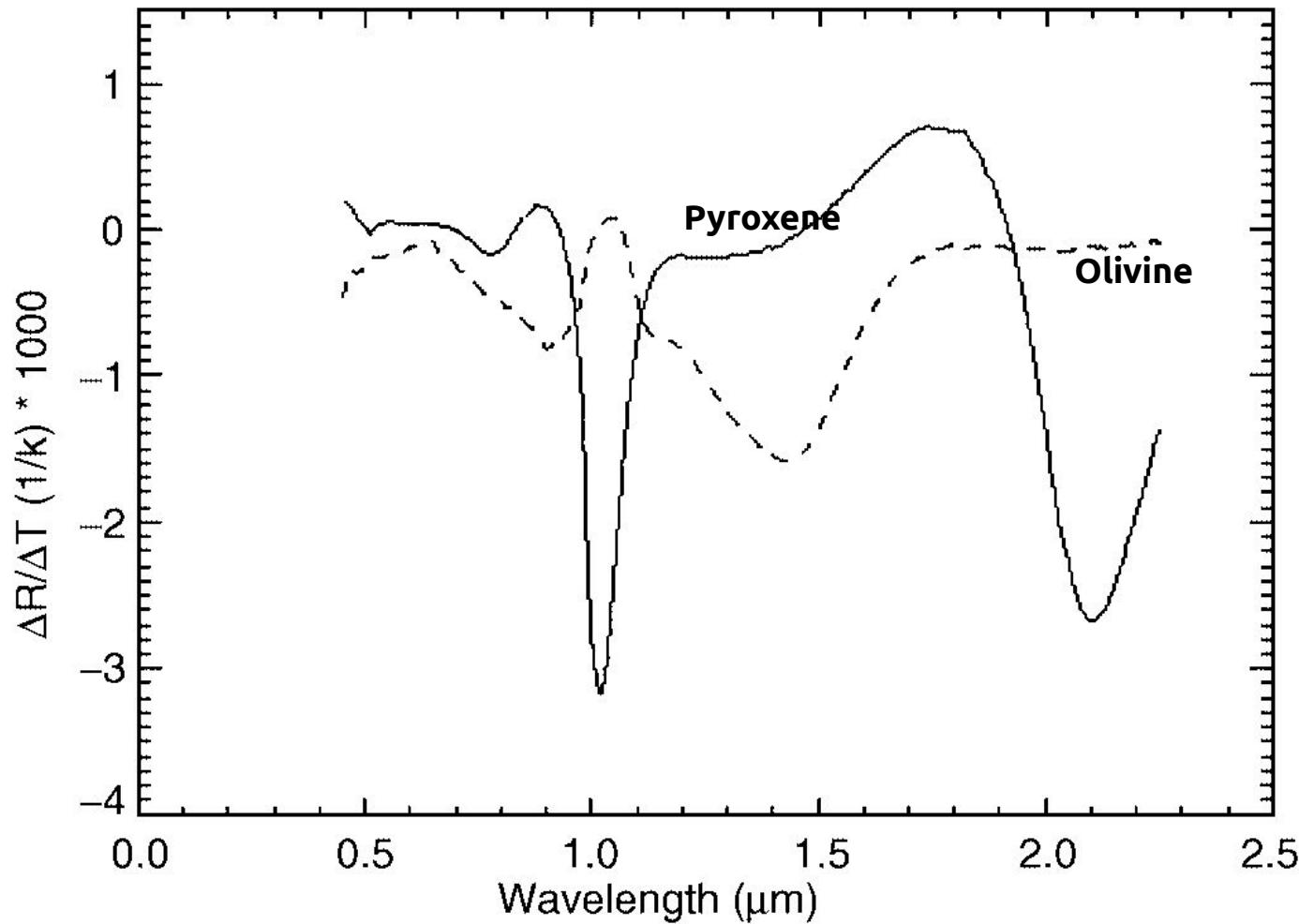


Plagioclase
100



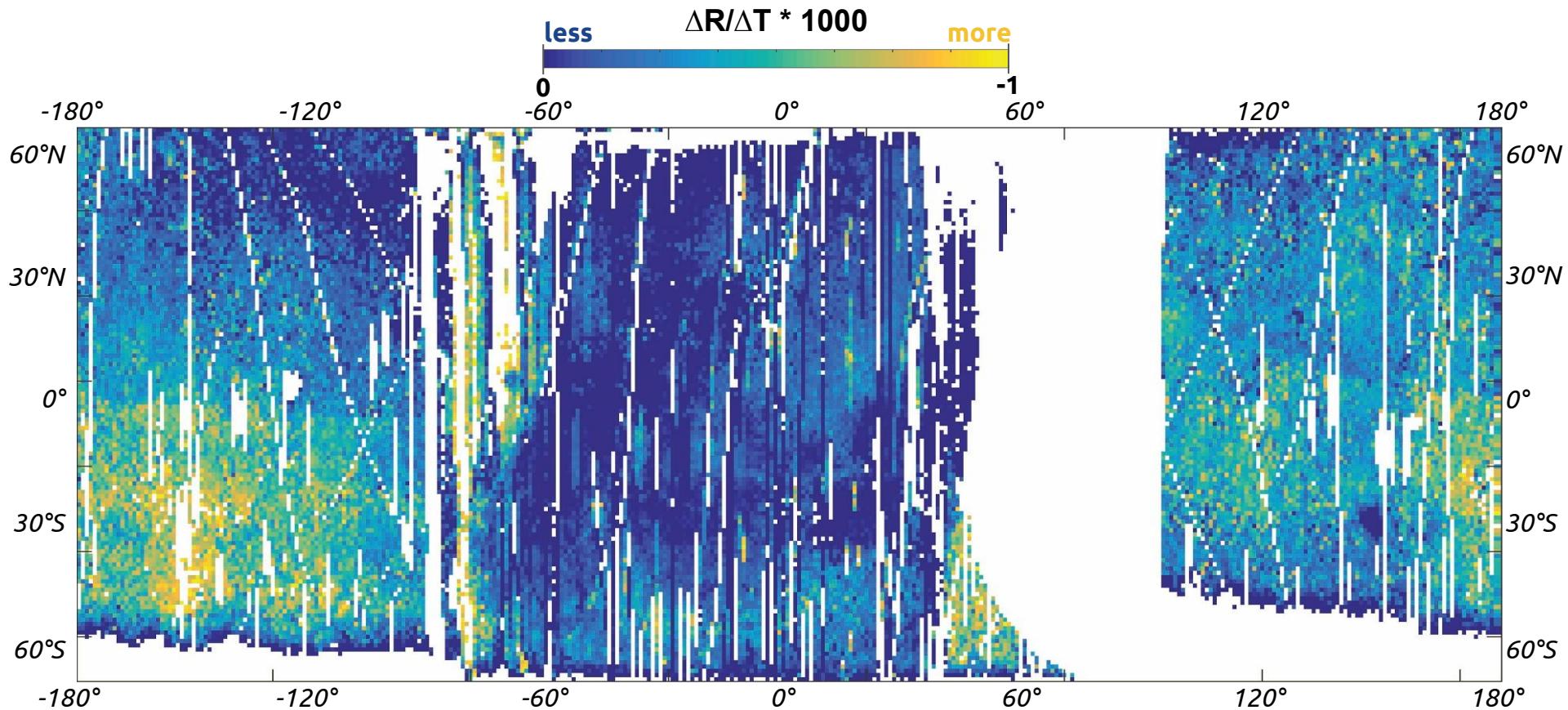
-1
 $\Delta R / \Delta T$
*1000
0

INTRODUCTION *temperature-dependent spectral changes*

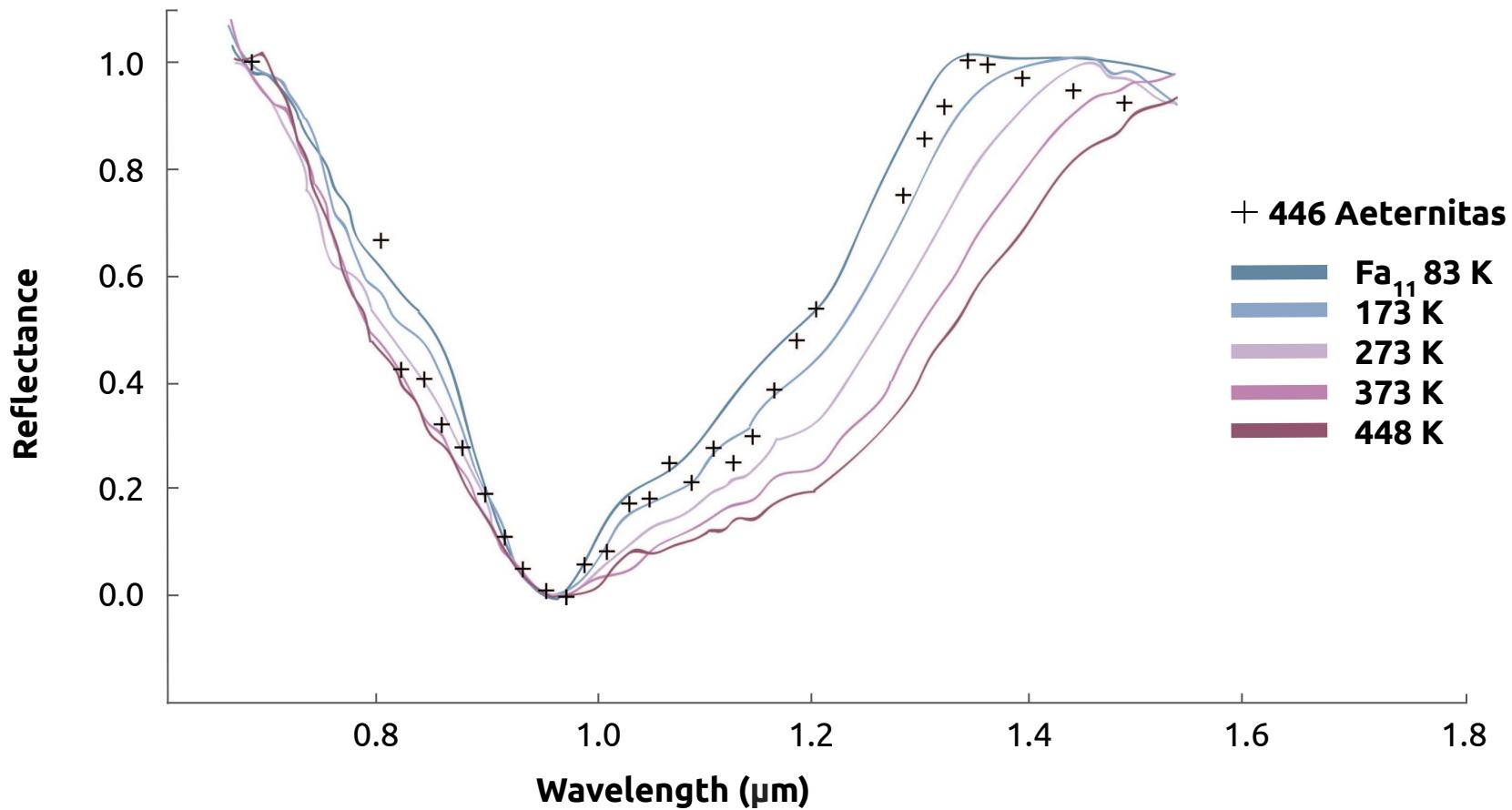


IMPLICATIONS LOLA as a mineralogical sensor

Where are the greatest temperature-dependent changes occurring?



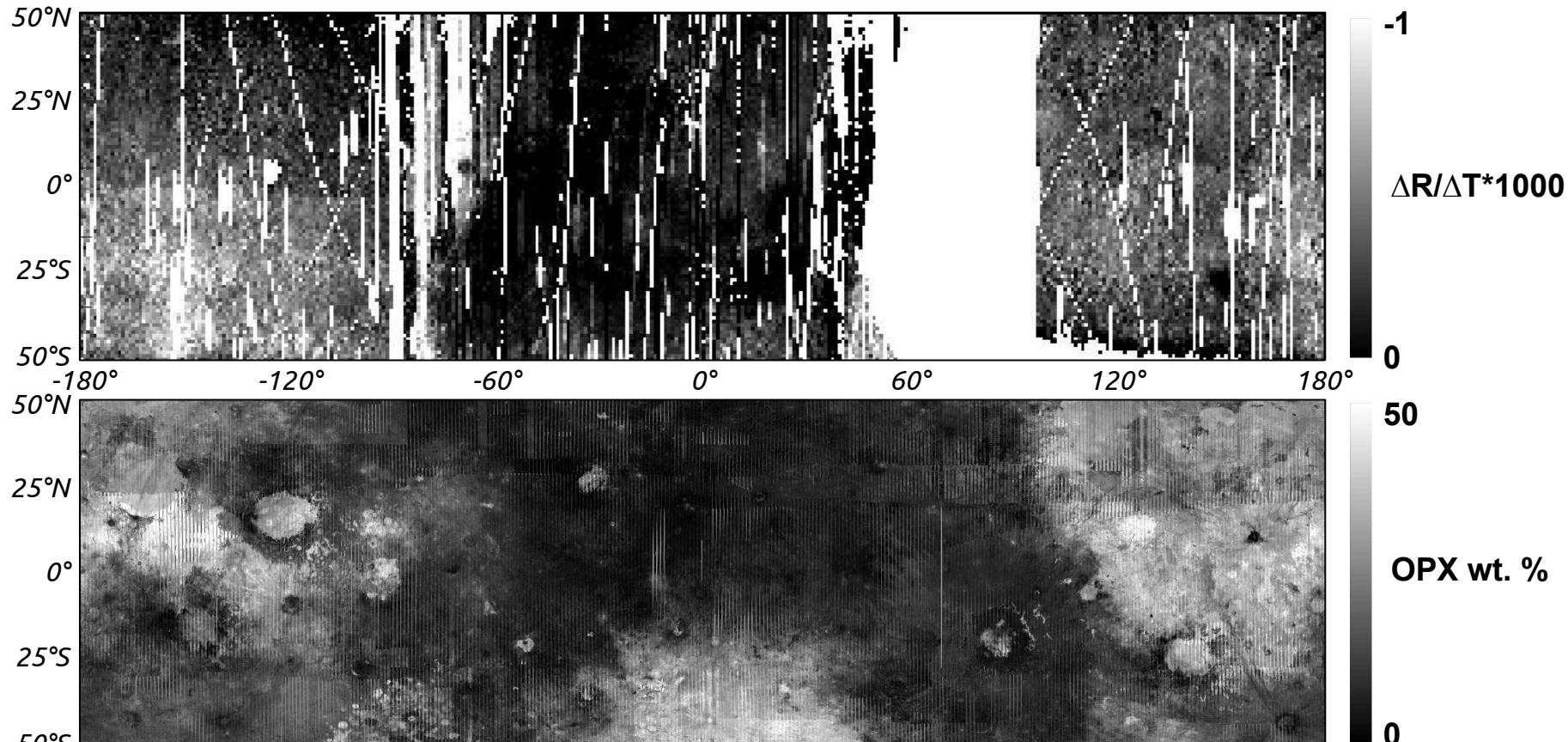
INTRODUCTION *temperature-dependent spectral changes*



Data from Lucey et al. (1998)

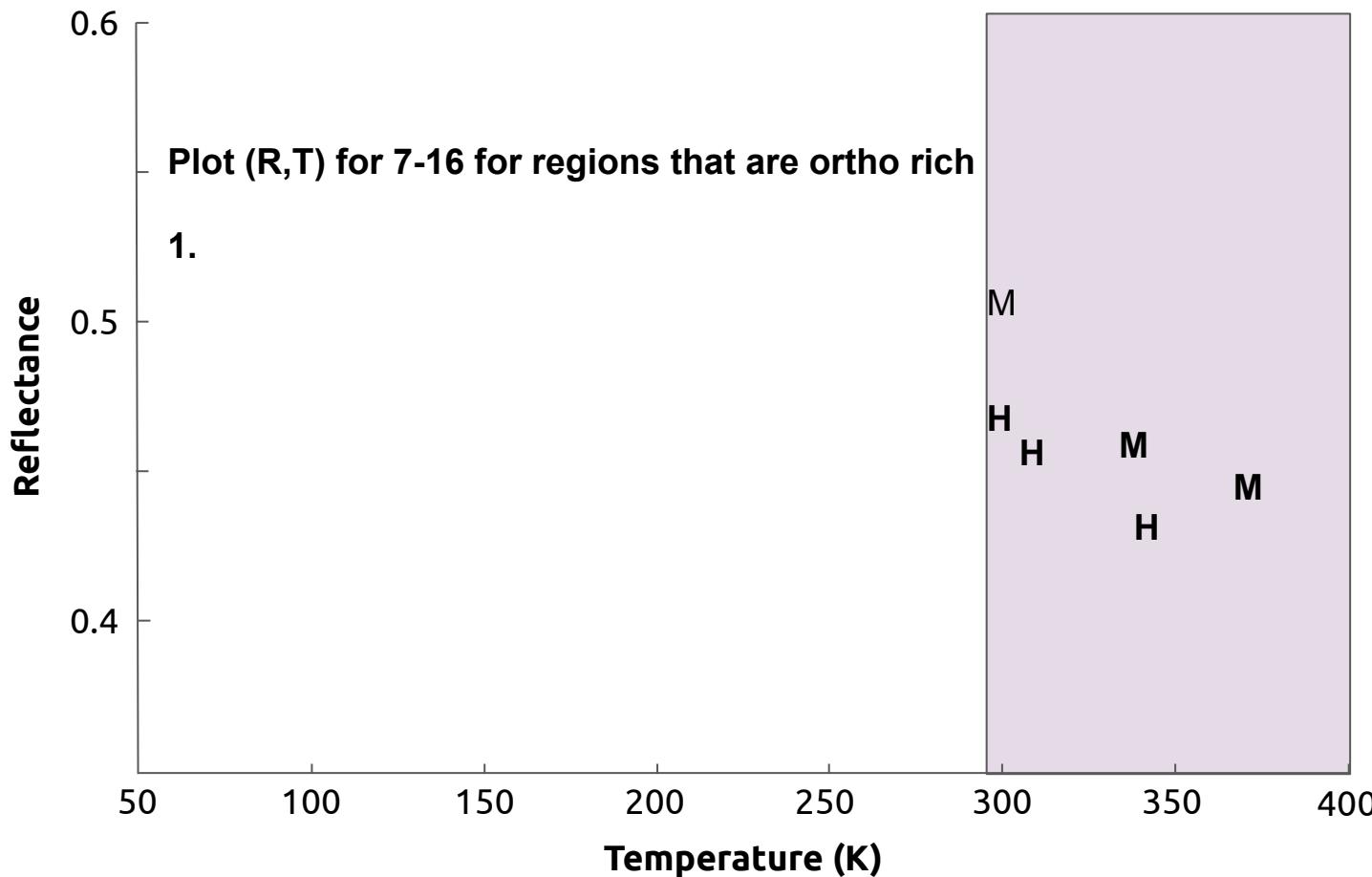
IMPLICATIONS LOLA as a mineralogical sensor

Where are the greatest temperature-dependent changes occurring?



Lemelin et al. (2016)

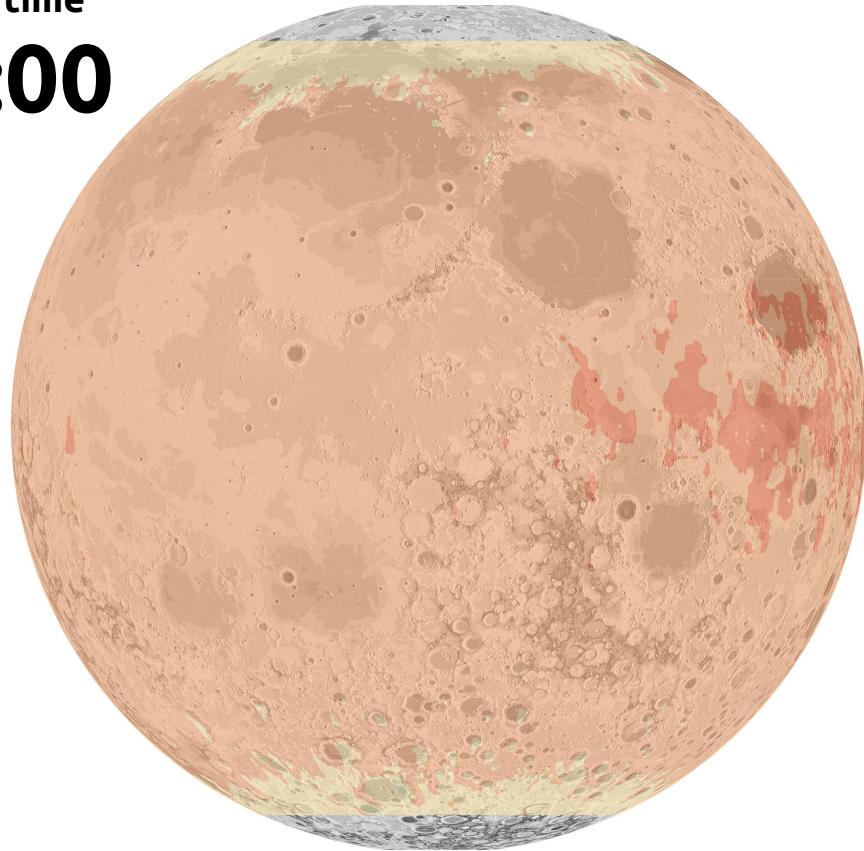
IMPLICATIONS LOLA as a mineralogical sensor



Data from Hinrichs et al. (1999)

RESULTS *diurnal reflectance changes*

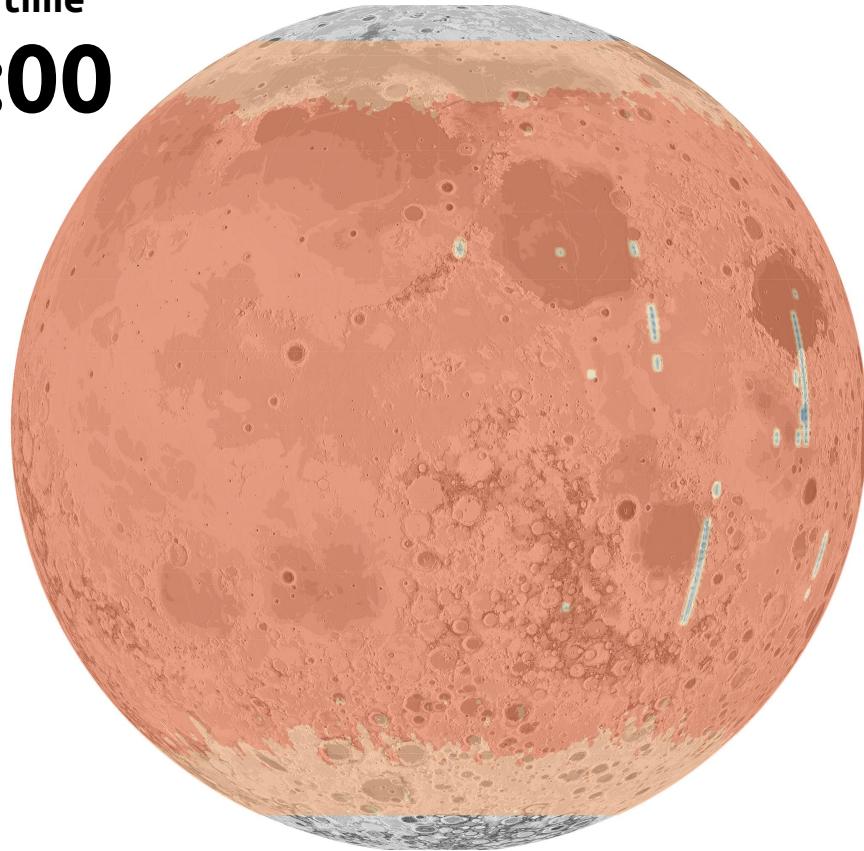
Local time
07:00



Temperature (K)
50 400

RESULTS *diurnal reflectance changes*

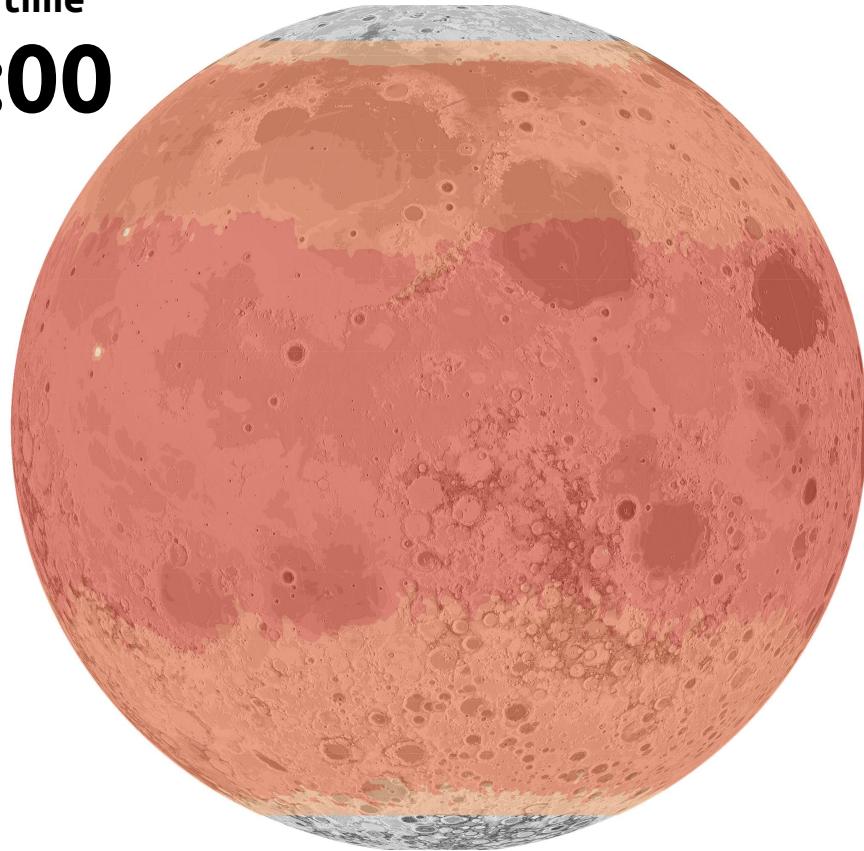
Local time
08:00



Temperature (K)
50 400

RESULTS *diurnal reflectance changes*

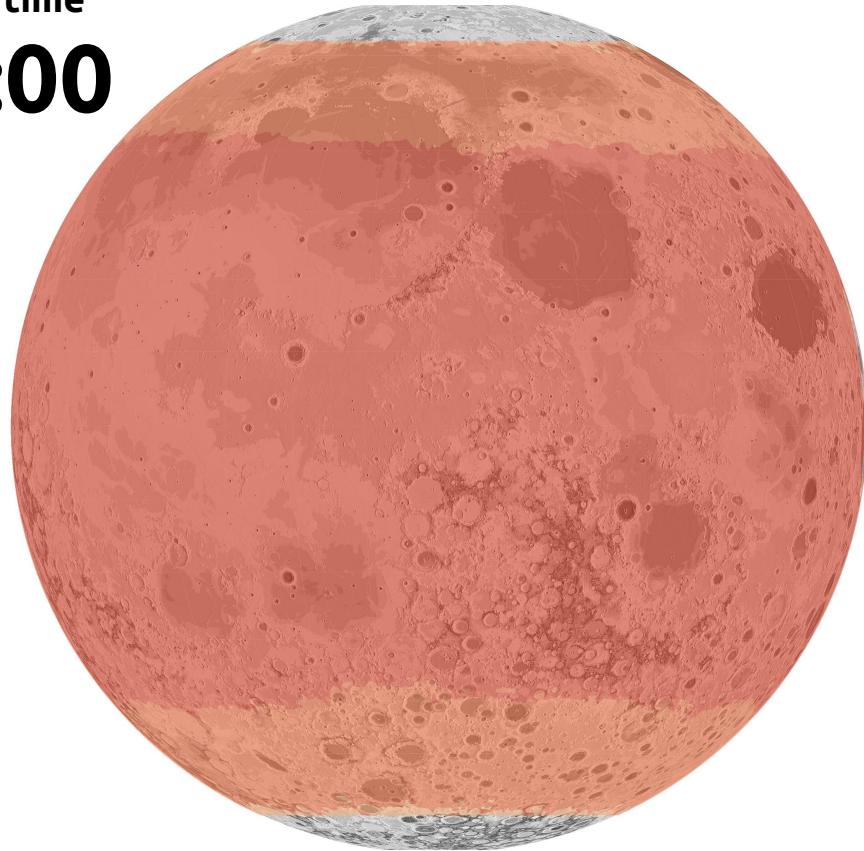
Local time
09:00



Temperature (K)
50 400

RESULTS *diurnal reflectance changes*

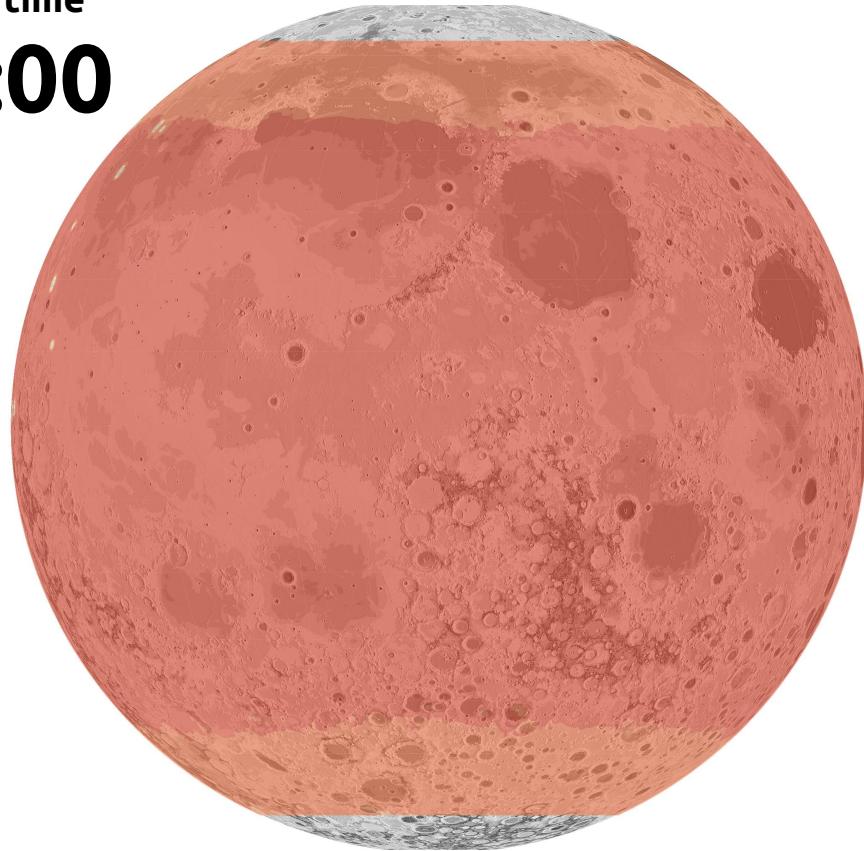
Local time
10:00



Temperature (K)
50 400

RESULTS *diurnal reflectance changes*

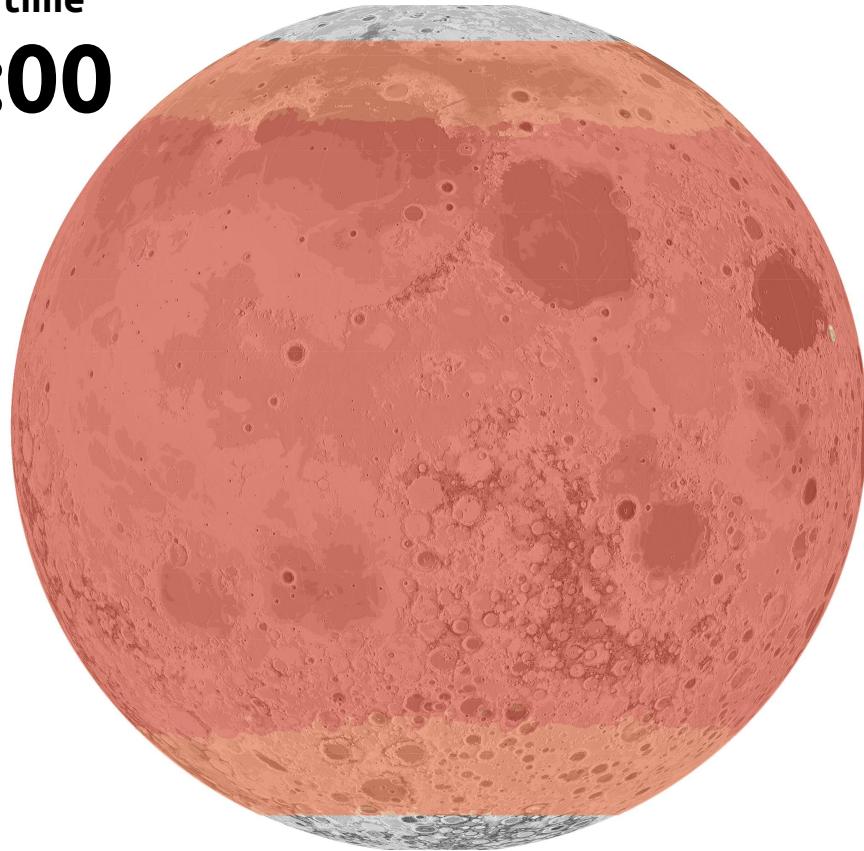
Local time
11:00



Temperature (K)
50 400

RESULTS *diurnal reflectance changes*

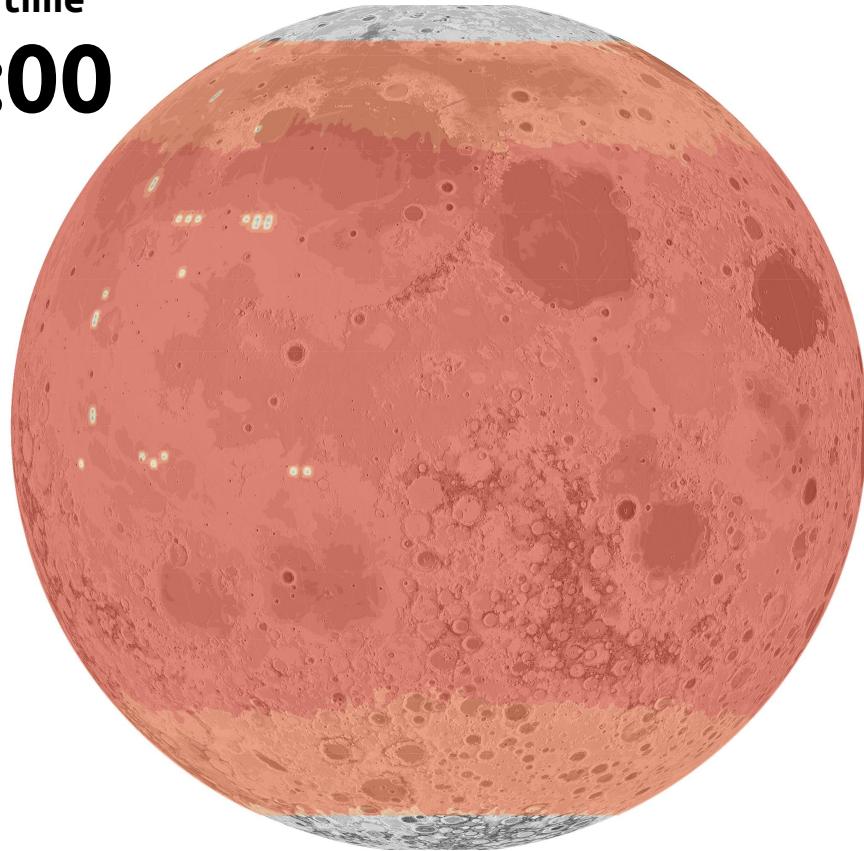
Local time
12:00



Temperature (K)
50 400

RESULTS *diurnal reflectance changes*

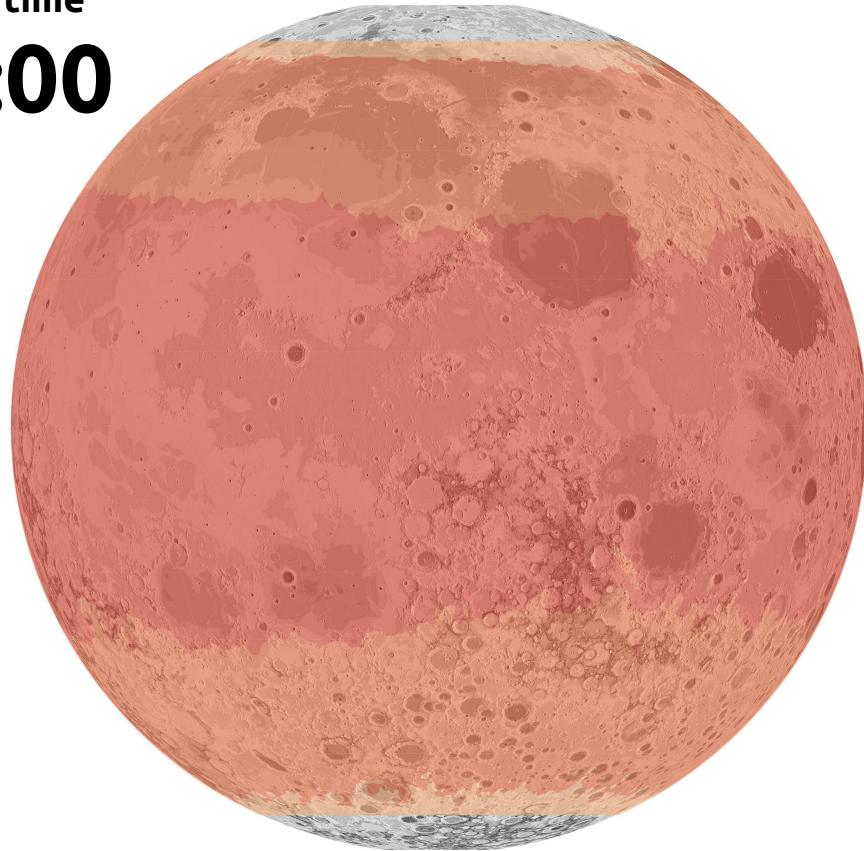
Local time
13:00



Temperature (K)
50 400

RESULTS *diurnal reflectance changes*

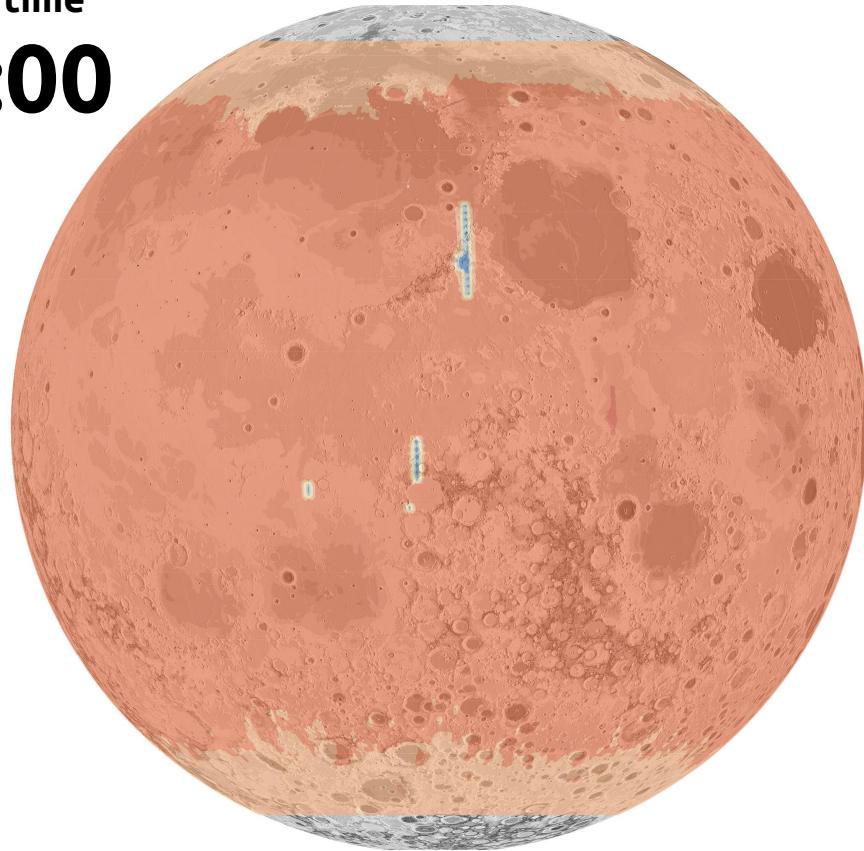
Local time
14:00



Temperature (K)
50 400

RESULTS *diurnal reflectance changes*

Local time
15:00



Temperature (K)
50 400

IMPLICATIONS *future measurements*

